[redacted]

# PROCEEDINGS

OF THE

# Indiana Academy of Science

## 1906

EDITOR, . . . . . . . . ARTHUR L. FOLEY

INDIANAPOLIS, IND.
1907

INDIANAPOLIS
WM. B. BURFORD, PRINTER
1907

THE STATE OF INDIANA,
EXECUTIVE DEPARTMENT,
May 7, 1907.

Received by the Governor, examined and referred to the Auditor of State for verification of the financial statement.

OFFICE OF AUDITOR OF STATE,
INDIANAPOLIS, May 18, 1907.

The within report, so far as the same relates to moneys drawn from the State Treasury, has been examined and found correct.

J. O. BILLHEIMER,
*Auditor of State.*

May 18, 1907.

Returned by the Auditor of State, with above certificate, and transmitted to Secretary of State for publication, upon the order of the Board of Commissioners of Public Printing and Binding.

FRED L. GEMMER,
*Secretary to the Governor.*

Filed in the office of the Secretary of State of the State of Indiana, May 18, 1907.

FRED A. SIMS,
*Secretary of State.*

Received the within report and delivered to the printer May 18, 1907.

HARRY SLOUGH,
*Clerk Printing Bureau.*

# TABLE OF CONTENTS.

## AN ACT TO PROVIDE FOR THE PUBLICATION OF THE REPORTS AND PAPERS OF THE INDIANA ACADEMY OF SCIENCE.

[Approved March 11, 1895.]

Preamble.

WHEREAS, The Indiana Academy of Science, a chartered scientific association, has embodied in its constitution a provision that it will, upon the request of the Governor, or of the several departments of the State government, through the Governor, and through its council as an advisory body, assist in the direction and execution of any investigation within its province, without pecuniary gain to the Academy, provided only that the necessary expenses of such investigation are borne by the State; and,

WHEREAS, The reports of the meetings of said Academy, with the several papers read before it, have very great educational, industrial and economic value, and should be preserved in permanent form; and

WHEREAS, The Constitution of the State makes it the duty of the General Assembly to encourage by all suitable means intellectual, scientific and agricultural improvement; therefore,

Publication of the Reports of the Indiana Academy of Science.

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana,* That hereafter the annual reports of the meetings of the Indiana Academy of Science, beginning with the report for the year 1894, including all papers of scientific or economic value, presented at such meetings, after they shall have been edited and prepared for publication as hereinafter provided, shall be published by and under the direction of the Commissioners of Public Printing and Binding.

Editing Reports.

SEC. 2. Said reports shall be edited and prepared for publication without expense to the State, by a corps of editors to be selected and appointed by the Indiana Academy of Science, who shall not, by reason of such services, have any claim against the State for compensation. The form, style of binding, paper, typography and manner and extent of illustration of such reports, shall be determined by the editors, subject to the approval of the Commissioners of Public Printing and Stationery. Not less than 1,500 nor more than 3,000 copies of each of said

Number of printed Reports.

reports shall be published, the size of the edition within said limits to be determined by the concurrent action of the editors and the Commissioners of Public Printing and Stationery: *Provided*, That not to exceed six hundred dollars ($600) shall be expended for such publication in any one year, and not to extend beyond 1896: *Provided*, That no sums shall be deemed to be appropriated for the year 1894.

Proviso.

Disposition of Reports.

SEC. 3. All except three hundred copies of each volume of said reports shall be placed in the custody of the State Librarian, who shall furnish one copy thereof to each public library in the State, one copy to each university, college or normal school in the State, one copy to each high school in the State having a library, which shall make application therefor, and one copy to such other institutions, societies or persons as may be designated by the Academy through its editors or its council. The remaining three hundred copies shall be turned over to the Academy to be disposed of as it may determine. In order to provide for the preservation of the same it shall be the duty of the Custodian of the State House to provide and place at the disposal of the Academy one of the unoccupied rooms of the State House, to be designated as the office of the Indiana Academy of Science, wherein said copies of said reports belonging to the Academy, together with the original manuscripts, drawings, etc., thereof can be safely kept, and he shall also equip the same with the necessary shelving and furniture.

Emergency.

SEC. 4. An emergency is hereby declared to exist for the immediate taking effect of this act, and it shall therefore take effect and be in force from and after its passage.

## AN ACT FOR THE PROTECTION OF BIRDS, THEIR NESTS AND EGGS.

[Indiana Acts 1905.]

Birds.

SECTION 602. It shall be unlawful for any person to kill, trap or possess any wild bird, or to purchase or offer the same for sale, or to destroy the nests or the eggs of any wild bird except as otherwise provided in this section. But this section shall not apply to the following named game birds: The Anatidæ, commonly called swans, geese, brant, river and sea duck: the Rallidæ, commonly known as rails, coots, mudhens, and gallinules; the Limicolæ, commonly known as shore birds, plovers, surf birds, snipe, woodcock, sandpipers, tattlers and curlews; nor to English or European house sparrows, crows, hawks, or other birds of prey. Nor shall this section apply to any person taking birds or their nests or eggs for scientific purposes under permit, as provided in the next section. Any person violating the provisions of this section shall, upon conviction, be fined not less than ten dollars nor more than fifty dollars.

SEC. 603. Permits may be granted by the Commissioner of Fisheries and Game to any properly accredited person, permitting the holder thereof to collect birds, their nests or eggs for strictly scientific purposes. In order to obtain such permit the applicant for the same must present to said Commissioner written testimonials from two well-known scientific men certifying to the good character and fitness of said applicant to be entrusted with such privilege, and pay to said Board one dollar therefor, and file with him a properly executed bond in the sum of two hundred dollars, payable to the State of Indiana, conditioned that he will obey the terms of such permit, and signed by at least two responsible citizens of the State as sureties. The bond may be forfeited and the permit revoked upon proof to the satisfaction of such Commissioner that the holder of such permit has killed any bird or taken the nests or eggs of any bird for any other purpose than that named in this section.

# Indiana Academy of Science.

## OFFICERS, 1906-1907.

PRESIDENT
DAVID M. MOTTIER.

VICE-PRESIDENT
GLENN CULBERTSON.

SECRETARY
LYNN B. MCMULLEN.

ASSISTANT SECRETARY
J. H. RANSOM.

PRESS SECRETARY
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TREASURER
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LYNN B. MCMULLEN,
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THOMAS GRAY,
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AMOS W. BUTLER,
W. A. NOYES,
J. C. ARTHUR,
O. P. HAY,
JOHN M. COULTER.

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| ICHTHYOLOGY | C. H. EIGENMANN. |
| HERPETOLOGY, MAMMALOGY, ORNITHOLOGY | AMOS W. BUTLER. |
| ENTOMOLOGY | W. S. BLATCHLEY. |

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NOMINATIONS,

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AUDITING,

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STATE LIBRARY,

W. S. BLATCHLEY, A. W. BUTLER, G. W. BENTON, J. S. WRIGHT, L. B. McMULLEN.

RESTRICTION OF WEEDS AND DISEASES,

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EDITOR,

ARTHUR L. FOLEY, Indiana University, Bloomington.

DIRECTORS OF BIOLOGICAL SURVEY,

STANLEY COULTER, CHARLES R. DRYER, M. B. THOMAS, C. H. EIGENMANN, J. C. ARTHUR.

RELATIONS OF THE ACADEMY TO THE STATE,

R. W. McBRIDE, WILLIAM WATSON WOOLLEN, C. A. WALDO, G. W. BENTON.

DISTRIBUTION OF THE PROCEEDINGS,

L. B. McMULLEN, L. J. RETTGER, JOHN S. WRIGHT, A. L. FOLEY, J. P. NAYLOR.

## OFFICERS OF THE INDIANA ACADEMY OF SCIENCE.

| | President. | Secretary. | Asst. Secretary. | Press Secretary. | Treasurer. |
|---|---|---|---|---|---|
| 1885–1886 | David S. Jordan | Amos W. Butler | | | O. P. Jenkins. |
| 1886–1887 | John M. Coulter | Amos W. Butler | | | O. P. Jenkins. |
| 1887–1888 | J. P. D. John | Amos W. Butler | | | O. P. Jenkins. |
| 1888–1889 | John C. Branner | Amos W. Butler | | | O. P. Jenkins. |
| 1889–1890 | T. C. Mendenhall | Amos W. Butler | | | O. P. Jenkins. |
| 1890–1891 | O. P. Hay | Amos W. Butler | | | O. P. Jenkins. |
| 1891–1892 | J. L. Campbell | Amos W. Butler | | | C. A. Waldo. |
| 1892–1893 | J. C. Arthur | Amos W. Butler | Stanley Coulter<br>W. W. Norman | | C. A. Waldo. |
| 1893–1894 | W. A. Noyes | C. A. Waldo | W. W. Norman | | W. P. Shannon. |
| 1894–1895 | A. W. Butler | John S. Wright | A. J. Bigney | | W. P. Shannon. |
| 1895–1896 | Stanley Coulter | John S. Wright | A. J. Bigney | | W. P. Shannon. |
| 1896–1897 | Thomas Gray | John S. Wright | A. J. Bigney | | W. P. Shannon. |
| 1897–1898 | C. A. Waldo | John S. Wright | A. J. Bigney | Geo. W. Benton | J. T. Scovell. |
| 1898–1899 | C. H. Eigenmann | John S. Wright | E. A. Schultze | Geo. W. Benton | J. T. Scovell. |
| 1899–1900 | D. W. Dennis | John S. Wright | E. A. Schultze | Geo. W. Benton | J. T. Scovell. |
| 1900–1901 | M. B. Thomas | John S. Wright | E. A. Schultze | Geo. W. Benton | J. T. Scovell. |
| 1901–1902 | Harvey W. Wiley | John S. Wright | Donaldson Bodine | Geo. W. Benton | J. T. Scovell. |
| 1902–1903 | W. S. Blatchley | John S. Wright | Donaldson Bodine | G. A. Abbott | W. A. McBeth. |
| 1903–1904 | C. L. Mees | John S. Wright | J. H. Ransom | G. A. Abbott | W. A. McBeth. |
| 1904–1905 | John S. Wright | Lynn B. M'Mullen | J. H. Ransom | G. A. Abbott | W. A. McBeth. |
| 1905–1906 | Robert Hessler | Lynn B. M'Mullen | J. H. Ransom | Charles R. Clark | W. A. McBeth. |
| 1906–1907 | D. M. Mottier | Lynn B. M'Mullen | J. H. Ransom | G. A. Abbott | W. A. McBeth. |

# CONSTITUTION.

## ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SEC. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science; to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other resources and riches of the State; to arrange and prepare for publication such reports of investigation and discussions as may further the aims and objects of the Academy as set forth in these articles.

Whereas, The State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or of one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

## ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident members or active members.

SEC. 2. Any person engaged in any department of scientific work, or in original research in any department of science, shall be eligible to active membership. Active members may be annual or life members. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars, and thereafter an annual fee of one dollar. Any person who shall at one time contribute

fifty dollars to the funds of this Academy may be elected a life member of the Academy, free of assessment. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Applications for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

SEC. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

## ARTICLE III.

SECTION 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a President, Vice-President, Secretary, Assistant Secretary, Press Secretary and Treasurer, who shall perform the duties usually pertaining to their respective offices, and in addition, with the ex-Presidents of the Academy, shall constitute an Executive Committee. The President shall, at each annual meeting, appoint two members to be a committee, which shall prepare the programs and have charge of the arrangements for all meetings for one year.

SEC. 2. The annual meeting of this Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the Executive Committee. There shall also be a summer meeting at such time and place as may be decided upon by the Executive Committee. Other meetings may be called at the discretion of the Ex-

ecutive Committee. The past Presidents, together with the officers and Executive Committee, shall constitute the Council of the Academy, and represent it in the transaction of any necessary business not especially provided for in this constitution, in the interim between general meetings.

SEC. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

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# BY-LAWS.

1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The President shall deliver a public address on the morning of one of the days of the meeting at the expiration of his term of office.

3. The Press Secretary shall attend to the securing of proper newspaper reports of the meetings and assist the Secretary.

4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the President and countersigned by the Secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of business.

# MEMBERS.

## *FELLOWS.*

| | | |
|---|---|---|
| R. J. Aley | *1898 | Bloomington. |
| J. C. Arthur | 1893 | Lafayette. |
| J. W. Beede | 1906 | Bloomington |
| George W. Benton | 1896 | Indianapolis. |
| A. J. Bigney | 1897 | Moore's Hill. |
| Katherine Golden Bitting | 1895 | Lafayette. |
| Donaldson Bodine | 1899 | Crawfordsville. |
| W. S. Blatchley | 1893 | Indianapolis. |
| H. L. Bruner | 1899 | Irvington. |
| Severance Burrage | 1898 | Lafayette. |
| A. W. Butler | 1893 | Indianapolis. |
| W. A. Cogshall | 1906 | Bloomington. |
| Mel. T. Cook | 1902 | Santiago, Cuba. |
| John M. Coulter | 1893 | Chicago, Ill. |
| Stanley Coulter | 1893 | Lafayette. |
| Glenn Culbertson | 1899 | Hanover. |
| E. R. Cumings | 1906 | Bloomington. |
| D. W. Dennis | 1895 | Richmond. |
| C. R. Dryer | 1897 | Terre Haute. |
| C. H. Eigenmann | 1893 | Bloomington. |
| Percy Norton Evans | 1901 | West Lafayette. |
| A. L. Foley | 1897 | Bloomington. |
| M. J. Golden | 1899 | Lafayette. |
| W. F. M. Goss | 1893 | Urbana, Ill. |
| Thomas Gray | 1893 | Terre Haute. |
| A. S. Hathaway | 1895 | Terre Haute. |
| W. K. Hatt | 1902 | Lafayette. |
| Robert Hessler | 1899 | Logansport. |
| H. A. Huston | 1893 | Lafayette. |
| Edwin S. Johonnatt | 1904 | Terre Haute. |
| Robert E. Lyons | 1896 | Bloomington. |
| W. A. McBeth | 1904 | Terre Haute. |

*Date of election.

| | | |
|---|---|---|
| **V. F. Marsters** | *1893 | Bloomington. |
| **C. L. Mees** | 1894 | Terre Haute. |
| **J. A. Miller** | 1904 | Bloomington. |
| **W. J. Moenkhaus** | 1901 | Bloomington. |
| **D. M. Mottier** | 1893 | Bloomington. |
| **J. P. Naylor** | 1903 | Greencastle. |
| **W. A. Noyes** | 1893 | Washington, D. C. |
| **Rolla R. Ramsey** | 1906 | Bloomington. |
| **J. H. Ransom** | 1902 | Lafayette. |
| **L. J. Rettger** | 1896 | Terre Haute. |
| **David Rothrock** | 1906 | Bloomington. |
| **J. T. Scovell** | 1894 | Terre Haute. |
| **Alex Smith** | 1893 | Chicago, Ill. |
| **W. E. Stone** | 1893 | Lafayette. |
| **Joseph Swain** | 1898 | Swarthmore, Pa. |
| **M. B. Thomas** | 1893 | Crawfordsville. |
| **C. A. Waldo** | 1893 | Lafayette. |
| **F. M. Webster** | 1894 | Champaign, Ill. |
| **Jacob Westlund** | 1904 | Lafayette. |
| **H. W. Wiley** | 1895 | Washington, D. C. |
| **John S. Wright** | 1894 | Indianapolis. |

* Date of election.

## *NON-RESIDENT MEMBERS.*

| | |
|---|---|
| **George H. Ashley** | Charleston, S. C. |
| **M. A. Brannon** | Grand Forks, N. D. |
| **J. C. Branner** | Stanford University, Cal. |
| **D. H. Campbell** | Stanford University, Cal. |
| **A. Wilmer Duff** | Worcester, Mass. |
| **B. W. Everman** | Washington, D. C. |
| **Charles H. Gilbert** | Stanford University, Cal. |
| **C. W. Green** | Columbia, Mo. |
| **C. W. Hargitt** | Syracuse, N. Y. |
| **O. P. Hay** | New York City. |
| **Edward Hughes** | Stockton, Cal. |
| **O. P. Jenkins** | Stanford University, Cal. |
| **D. S. Jordan** | Stanford University, Cal. |

J. S. Kingsley . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Tufts College, Mass.
D. T. MacDougal . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bronx Park, New York City
T. C. Mendenhall . . . . . . . . . . . . . . . . . . . . . . . . . . . . Worcester, Mass.
Alfred Springer . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Cincinnati, Ohio.
L. M. Underwood . . . . . . . . . . . . . . . . . . . . . . . . . . . . New York City.
Robert B. Warder . . . . . . . . . . . . . . . . . . . . . . . . . . . . Washington, D. C.
Ernest Walker . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Clemson College, S. C.

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## *ACTIVE MEMBERS.*

George Abbott . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
Edward Hugh Bangs . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
Walter D. Baker . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
Harry Eldridge Bishop . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
William N. Blanchard . . . . . . . . . . . . . . . . . . . . . . . . . Greencastle.
Lester Black . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Lee F. Bennett . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Valparaiso.
Charles S. Bond . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Richmond.
Fred J. Breeze . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Remington.
E. M. Bruce . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Terre Haute.
Lewis Clinton Carson . . . . . . . . . . . . . . . . . . . . . . . . . Detroit, Mich.
Herman S. Chamberlain . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
E. J. Chansler . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bicknell.
Otto O. Clayton . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Geneva.
Howard W. Clark . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Chicago, Ill.
H. M. Clem . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Monroeville.
Charles Clickener . . . . . . . . . . . . . . . . . . . . . . . . . . . . Silverwood, R. D. No. 1
Charles A. Coffey . . . . . . . . . . . . . . . . . . . . . . . . . . . . Petersburg.
Ulysses O. Cox . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Terre Haute.
William Clifford Cox . . . . . . . . . . . . . . . . . . . . . . . . . Columbus.
J. A. Cragwall . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Crawfordsville
M. E. Crowell . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Franklin.
Lorenzo E. Daniels . . . . . . . . . . . . . . . . . . . . . . . . . . . Laporte.
S. C. Davisson . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bloomington.
Charles C. Deam . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bluffton.
Martha Doan . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Westfield.
J. P. Dolan . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Syracuse.

| | |
|---|---|
| Herman B. Dorner | Lafayette. |
| Hans Duden | Indianapolis. |
| Arthur E. Dunn | Logansport. |
| Herbert A. Dunn | Logansport. |
| Max Mapes Ellis | Vincennes. |
| M. N. Elrod | Columbus. |
| Samuel G. Evans | Evansville. |
| William P. Felver | Logansport. |
| Wilbur A. Fiske | Richmond. |
| W. B. Fletcher | Indianapolis. |
| Austin Funk | Jeffersonville. |
| John D. Gabel | Montpelier. |
| Andrew W. Gamble | Logansport. |
| H. O. Garman | Lafayette. |
| Charles W. Garrett | Pittsburg, Pa. |
| Robert G. Gillum | Terre Haute. |
| Vernon Gould | Rochester. |
| Frank Cook Greene | New Albany |
| Walter L. Hahn | Mitchell. |
| Mary T. Harman | Odon. |
| Victor Hendricks | St. Louis. |
| John P. Hetherington | Logansport. |
| C. E. Hiatt | Bloomington. |
| John E. Higdon | Indianapolis. |
| Frank R. Higgins | Terre Haute. |
| S. Bella Hilands | Madison. |
| John J. Hildebrandt | Logansport. |
| G. E. Hoffman | Logansport. |
| Allen D. Hole | Richmond. |
| Lucius M. Hubbard | South Bend. |
| John N. Hurty | Indianapolis. |
| C. F. Jackson | Greencastle. |
| Wm. J. Jones, Jr | West Lafayette. |
| O. L. Kelso | Terre Haute. |
| Frank D. Kern | Lafayette. |
| Charles T. Knipp | Urbana, Ill. |
| R. W. McBride | Indianapolis. |
| Richard C. McClaskey | Terre Haute. |

| | |
|---|---|
| N. E. McIndoo | Lyons. |
| Lynn B. McMullen | Indianapolis. |
| Edward G. Mahin | West Lafayette. |
| James E. Manchester | Vincennes. |
| Wilfred H. Manwaring | Bloomington. |
| William Edgar Mason | Borden. |
| Clark Mick | Berkley, Cal. |
| G. Rudolph Miller | Indianapolis. |
| Richard Bishop Moore | Indianapolis. |
| Fred Mutchler | Terre Haute. |
| Charles E. Newlin | Irvington. |
| John F. Newsom | Stanford University, Cal. |
| D. A. Owen | Franklin. |
| Rollo J. Peirce | Indianapolis. |
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| James A. Price | Ft. Wayne. |
| A. H. Purdue | Fayetteville, Ark. |
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| George L. Roberts | Muncie. |
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| Will Scott | Bloomington. |
| Charles Wm. Shannon | Bloomington. |
| Fred Sillery | Indianapolis. |
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| Albert Smith | Lafayette. |
| Essie Alma Smith | Bloomington. |
| C. Piper Smith | Pacific Grove, Cal. |
| J. M. Stoddard | Indianapolis. |
| Albert W. Thompson | Owensville. |
| W. B. Van Gorder | Worthington. |
| H. S. Voorhees | Ft. Wayne. |
| Frank B. Wade | Indianapolis |
| Daniel T. Weir | Indianapolis. |
| Guy West Wilson | Bronx Park, N. Y. |
| William Watson Woollen | Indianapolis. |
| Herbert Milton Woolen | Indianapolis. |

| | |
|---|---|
| J. F. Woolsey | Indianapolis. |
| Wm. J. Young | Hyattsville, Md. |
| Lucy Youse | Terre Haute. |
| Charles Zeleny | Bloomington. |

| | |
|---|---|
| Fellows | 53 |
| Non-resident members | 20 |
| Active members | 107 |
| Total | 180 |

**Note.**—For list of Foreign Correspondents, see Proceedings of 1904.

# PROGRAM

OF THE

## *TWENTY-SECOND ANNUAL MEETING,*

## INDIANAPOLIS, INDIANA.

**Held in Shortridge High School Building, November 30 and December 1, 1906.**

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*President's Address—The Evolution of Medicine in Indiana ............ Robert Hessler

### GENERAL.

*1. A State Natural Park, 5m ............ Fred J. Breeze
*2. Some Results from the Study of Life Insurance Problems, 10m ............ C. H. Beckett
3. The Sex Ratio in the Fruit Fly and its Control by Selection, 10m ............ W. J. Moenkhaus
4 An Outline of the Course in the Experimental Engineering Laboratory of Purdue University, 10m ............ W. O. Teague
*5. The United States Geological Survey ............ H. M. Wilson, Chief Geographer
*6. Drainage Area of the East Fork of White River, 10m ............ G. W. Shannon
*7. Steps in the Development of a Smokeless City ............ W. F. M. Goss
*8. Experimental Studies of Reinforced Concrete, 7m ............ W. K. Hatt
*9. Reclamation Possibilities of the Great Plains, 30m ............ J. W. Beede
*10. How the Body Fights Disease, 15m ............ W. H. Manwaring
11. The State Production and Control of Vaccines and Antitoxines, 15m ............ L. W. Famulener
*12. Recurrence of Uroglena in the Lafayette City Water Supply, 5m ............ Severance Burrage
*13. Laboratory Tests on certain Liquid Dentifrices and Mouth-washes, 15m ............ Severance Burrage
*14. A Critical Study of Methods of Sweeping Rooms and Wards in Hospitals, 10m ............ Severance Burrage

*The program committee suggests that papers 6 to 9 inclusive be heard at the Friday evening meeting and that the Academy invite its friends.

### MATHEMATICS.

*15. On the Reduction of Partial Differential Equations of the Fourth Order, 10m ............ Charles Haseman
16. The Determination of a Certain Family of Surfaces, 10m ............ Wm. H. Bates
*17. Concerning Differential Invariants, 10m ............ D. A. Rothrock
*18. Conjugate Functions and Canonical Transformations, 10m ............ D. A. Rothrock
19. On the Formula for the Area of a Curve in Polar Coordinantes, 10m ............ Jacob Westlund
20. A Group of Scrolls Connected with a Steam Locomotive, 10m ............ C. A. Waldo

### CHEMISTRY.

*21. Notes on Salt Lime, 10m ............ F. B. Wade
*22. Sugar and Sourness, 10m ............ P. N. Evans
*23. A Simple Method of Measuring Hydrolysis, 10m ............ G. A. Abbott
*24. The Ionization of the Successive Hydrogens of Orthophosphoric Acid, 10m ............ G. A. Abbott
25. Thiocarbonylsalicylamide and Derivatives, 5m ............ R. E. Lyons and Elizabeth Shirley
26. Some Complex Ureids, 5m ............ R. E. Lyons and James Currie
27. A Volumetic Method for the Estimation of Selenic Acid, 5m ............ R. E. Lyons and C. G. Carpenter
*28. The Solubility of Uranium X in Ammonium Carbonate and the Variations in the Activity of Some Uranium Compounds, 10m ............ R. B. Moore and Herman Schlundt
*29. The Separation of Iron and Manganese by means of Pyridine, 5m ............ R. B. Moore and Ivy Miller

## PHYSICS



## BOTANY.



## ZOOLOGY.



## GEOLOGY.



*Papers marked with a star were read.

# THE TWENTY-SECOND ANNUAL MEETING OF THE INDIANA ACADEMY OF SCIENCE.

The twenty-second annual meeting of the Indiana Academy of Science was held in Indianapolis, Thursday, Friday and Saturday, November 29, 30, and December 1, 1906.

Thursday, at 6 p. m., twenty members of the Academy dined together at the Claypool Hotel. Following the dinner the Executive Committee met in regular session at the hotel headquarters.

President Robert Hessler called the Academy to order at 9:30 Friday morning, in the teachers' assembly room at Shortridge High School. The transaction of business and the reading of papers occupied the attention of the Academy until 11 a. m., when Dr. Hessler read his paper entitled: "The Evolution of Medicine in Indiana."

Following this address came an adjournment until 2 p. m., when other papers came up for reading and discussion. At night papers of general interest were read and the friends of the Academy were invited to be present. On Saturday morning all unsettled business was cared for and the remainder of the papers were heard, when the Academy adjourned.

## THE SPRING MEETING OF 1906.

The spring meeting of 1906 was held in New Harmony, Indiana, May 25 and 26.

The party reached New Harmony Friday afternoon, and in the evening was entertained at a meeting planned by the residents. Frank Owen Fitton presided at this meeting, and talks were made by Miss Carrie Pelham, on "The Community Life of New Harmony," and the Rev. William DuHamel on "The Scientific History of New Harmony."

Saturday was spent in exploring the town and its surroundings.

# PRESIDENT'S ADDRESS.

## The Evolution of Medicine in Indiana.

Robert Hessler, A. M., M. D.

On looking over the addresses of our past Presidents, I observe that they have usually dwelt upon subjects in which they were especially interested, and I feel it but natural that I should do likewise.

In addressing you I am not unmindful of the fact that the people as a whole are behind you, are in a measure represented by you as leaders in scientific thought, and that a discourse should be shaped accordingly. All that I should like to say would require much time; what I can say in the brief time allotted must be suggestive rather than a full and exact statement of scientific facts and deductions.

The subject is a vast one, but I shall consider it briefly from three standpoints: First, the evolution of the medical student and the coming of the medical man into our State; second, the evolution of diseases and the coming in of new diseases, or, rather, the introduction of old diseases into a new locality; and lastly, the changes in methods of the treatment of diseases.

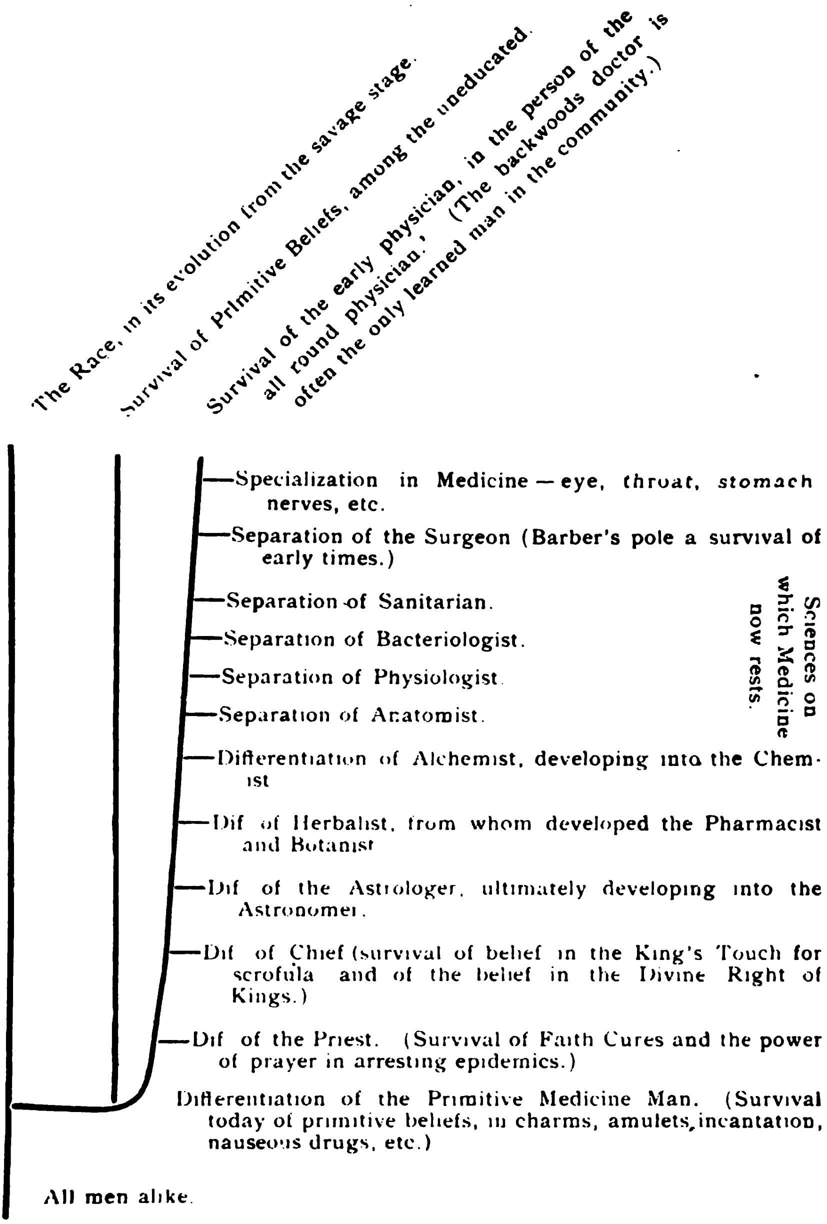
Art precedes science everywhere. Plants were used and cultivated before there was a science of botany; many of the processes underlying chemistry were known before there was a science of chemistry. Likewise the sick were treated before there was a science of medicine. There are not wanting those who deny that there is a science of medicine and who assert that it is simply an art based on many sciences—on anatomy, bacteriology, chemistry, and so on through the alphabet, but the prevailing view is that there is a science of medicine. Whichever view we adopt must lead to the conclusion that the greater a man's knowledge of science, the better a practitioner he will likely be, other things being equal.

What is the reason, I have been asked, so few of the Indiana physicians are members of the Indiana Academy of Science? If physicians are scientific men, why are so few members of the Academy? My usual reply is that our physicians are so busy fighting disease and giving relief to the sick that they have no time—such a reply satisfies many and places the doctors in a good light. But such a reply does not quite fit in case of the question: Why are so many doctors not members of a progressive medical society? Or, Why do so few contribute to the scientific medical literature of the State? Perhaps a brief review of the evolution of medicine in Indiana will enable us to draw some just conclusions.

As sciences do not spring up suddenly, but are a matter of slow growth, so likewise the accumulated stock of knowledge is not suddenly transferred to a new country; it takes a long time to bring it in, and our State is no exception.

THE PRIMITIVE MEDICINE MAN: The primitive medicine man was the first to differentiate from the race; when all hunted and fished, he alone stood apart and in the course of time separated more and more. As knowledge was brought together, there was a further differentiation, sciences crystallized out and pursued independent courses—but in their application are always of benefit to man. Where the early medicine man held all the knowledge of his race or tribe, in the course of time there arose a number of learned men. The man who studied the stars in time developed into an astrologer and later on into an astronomer, just as the herbalist developed in time into a pharmacist or botanist. (The diagram is intended to show this relationship in a general way. The survival of old time beliefs and methods of treating diseases being represented by a line parallel to the development of the race, we need only think of the use of charms and amulets, of faith-cures, the administration of nauseous drugs, and so on, to gain an idea of how much still survives.)

INDIAN MEDICINE MAN: The native Indian medicine man belonged to a race still in the childhood of civilization, a race in the hunting and fishing stage, and his beliefs and methods of treating disease were on a level with such a stage; moreover at the time the white man first came in, the Indians had few diseases to contend with. Contrary to the popular belief, the modern physician can learn nothing from the Indian medicine man, though the life of the Indian can teach him many things pertaining to the value of simple food, pure water and air, with out-of-door exercise.


The Race, in its evolution from the savage stage.
Survival of Primitive Beliefs, among the uneducated.
Survival of the early physician, in the person of the all round physician. (The backwoods doctor is often the only learned man in the community.)
—Specialization in Medicine — eye, throat, stomach nerves, etc.
—Separation of the Surgeon (Barber's pole a survival of early times.)
—Separation of Sanitarian.
—Separation of Bacteriologist.
—Separation of Physiologist.
—Separation of Anatomist.
Sciences on which Medicine now rests.
—Differentiation of Alchemist, developing into the Chemist
—Dif of Herbalist, from whom developed the Pharmacist and Botanist
—Dif of the Astrologer, ultimately developing into the Astronomer.
—Dif of Chief (survival of belief in the King's Touch for scrofula and of the belief in the Divine Right of Kings.)
—Dif of the Priest. (Survival of Faith Cures and the power of prayer in arresting epidemics.)
Differentiation of the Primitive Medicine Man. (Survival today of primitive beliefs, in charms, amulets, incantation, nauseous drugs, etc.)
All men alike.

Early Indiana Physicians: When the pioneer came to our territory he left his old diseases behind, but in the course of time they followed him, and he had to make the best of it. Until a country is sufficiently settled to support an educated physician, none comes in. Men were influenced then by the same motives that influence them today. No well educated physician today thinks of settling in the backwoods; but as soon as a settlement is made and a village arises, some venturesome spirit is apt to come in. As a matter of fact the first Indiana physicians were men connected with the United States army posts along the Wabash river, little over a century ago; unfortunately they left no records of their observations.

Physicians proper began to come in during the first decade of the past century, but there are scarcely any medical records prior to the year 1820. The early physicians led a strenuous life; there were no roads and the sick were scattered over a large area; it was a horseback and saddlebag life. Few had time or inclination to write—to the few who did write we owe all our knowledge of those days. Medical books then were few and costly; a man with one book in each branch of medicine was indeed a rarity. Medical journals were equally rare, and the fact that some of the early Indiana physicians took the London Lancet speaks volumes for their learning and ambition.

The educated physician soon had apprentices; that is, farmers' sons, who learned the rudiments of the profession and then began their own work; few went to a medical school. For a long time there were only two medical schools this side of the Alleghanies—at Lexington, Ky., and at Cincinnati—and to attend these meant a long trip over roads at times almost impassable. At first there were simple medical laws, but these were abolished, and after 1843 the field was open to all. Just as bad money drives out the good, so bad physicians drove out the good, or prevented good ones from coming in, and for a long time medical affairs went backward. But we must not forget that Indiana retrograded generally during this time. In 1850 Indiana was the eighth State in point of number of inhabitants, but ranked twenty-third in illiteracy—lower than all the slave states but three. The term "Hoosier" was a term of reproach, from which our physicians did not escape, and sharp criticism was passed on some of our civil war surgeons.

The early Indiana physicians had few kinds of diseases to contend with, but these few made up in number of cases for the lack of kind. Malaria ravaged frightfully and dominated all diseases. The standard

treatment for malaria, as for most other diseases, was bleeding, purging and vomiting, and the use of calomel, whisky and bark, the latter in time displaced by quinine.

In the course of time the pains and aches of civilization came in. I have heard old settlers speak of them as "new-fangled diseases," and there came also a revulsion against old methods of treatment. In the absence of restraining medical laws, a host of practitioners soon appeared; some of these became quite skillful, but one is reminded of the story of the man who expressed his admiration at the skill of the oculist who had just operated on him; the oculist admitted that he was skilled, adding, "But I spoiled half a bushel of eyes in learning to perform that operation."

Gradually the "isms" and "pathies" of medicine appeared, most of them a protest against some of the absurdities of the old practitioners. There are no "isms" nor "pathies" among the sciences on which medicine rests—anatomy, bacteriology, chemistry, and so on, are free from them; but when it comes to therapeutics or treatment, one-half of the doctors think the other half wrong. However a number of established facts are gradually accumulating and in the course of time there will be a science of therapeutics, in which serum therapy will, no doubt, hold a prominent place, and many of the drugs of today only a minor one.

With the advance of civilization a number of well defined diseases tend to diminish, but with a massing of humanity a host of ills tend to increase. There are any number of affections that scarcely rise to the dignity of a disease. Prescribing becomes largely a prescribing for symptoms, and many of the sick do their own prescribing; some go to a physician only as a last resort. Many are unwilling to pay the physician for the time it takes to investigate, and so the physician himself simply prescribes for the symptoms. Some physicians are so busy doing this that they have no time for study or to attend the meetings of their medical society, much less attend and take part in the deliberations of any scientific society. The bane of the scientific physician is the busy practitioner who flits from one patient to another, never studying any case in detail nor taking time for study, or manifesting any interest in the progress of medicine. The number of men who have contributed to the annual Transactions of the Indiana State Medical Society is remarkably small; where a few make frequent contributions, many make none at all.

MEDICAL SCHOOLS: For a long time our State had no school for the education of physicians and the more ambitious students of medicine had

to go elsewhere. More than fifty years ago the doctors of Indiana were discussing the advisability of establishing a medical college; there were arguments pro and con. Some believed that if we could not have a good school, we had best have none. Since then many medical colleges have come into existence and continued for variable periods of time. Some "went under" early, others experienced the hardships of existence as private institutions. The struggle is still going on. Indiana is behind the times; she is still without a medical school controlled by the State. Every civilized country sooner or later is compelled to assume control of medical education.

The art of medicine has made progress in Indiana, but the science lags behind; so far, our State has made little real addition to the science of medicine.

Although at the time of the passage of the common school law, only about fifty years ago, the term Hoosier was one of reproach, the advent of the schoolmaster and State education soon changed that, and today we take pride in being called Hoosiers—it is becoming a term of honor rather than of reproach. We have wholly outgrown our former reputation, and Indiana literary productions are known the world over.

The old medical schools did their work well; it was a practical work; but until the State takes charge of medical education and sets a good standard, little advance in medical science is to be expected.

Art precedes science everywhere. Our own physicians have been so busy applying the knowledge already extant that they have not had time to make original observations, and few have published their observations. But the time will come when our physicians will add to the scientific literature of medicine—the rise of general education and of literature in our State foreshadows it.

### THE ADVENT OF DISEASES.

The coming in of new diseases can perhaps be best understood in the light of the analogy of the coming in of new weeds. Weeds and diseases can be compared in many ways, but after a time analogies fail and each must be studied separately. Pointing out analogies often leads men to think, and in this light they are justifiable.

EARLY BOTANISTS AND EARLY WEEDS—EARLY PHYSICIANS AND EARLY DISEASES: Of the prevalence of the early weeds of our State we know

but little; there were no competent observers. A farmer might fight weeds all his life and yet know but little about them, about their characteristics and properties, or their classification, and he is very apt to confound species. A farmer usually simply learns to do certain things, only a few inquire into the reason why or into the nature of the thing itself; we call these few progressive farmers.

The erratic Rafinesque was perhaps the first botanist who visited our State, but he left no records of Indiana plants. The first botanist to make a local list was Dr. A. Clapp, of New Albany, in the early thirties; at that time many European weeds had already wandered in. Since then a number of local lists have been made, some of them by physicians who botanized as a recreation. The first State Catalogue was that of Coulter, Barnes and Arthur, published in 1881. The complete State Catalogue of Stanley Coulter did not appear until 1900; since then a number of additional lists have appeared in the Proceedings of our Academy. New plants are constantly arriving, brought in from other States and countries; of these new arrivals many are weeds and of these some remain and become common. Where at first there were but few observers of new arrivals, now there are many, and new weeds are soon recognized and reported.

If it requires a botanist (even though only an amateur who submits to the superior knowledge of the expert) to distinguish between weeds, it must be evident that an educated physician is required to distinguish between diseases and to record the arrival of new ones. A man may fight disease or diseases all his life without knowing anything about Das Wesen der Krankheit; indeed, it is painful to admit that the best physicians have to fight diseases about whose real nature they know but little; like the farmer and his weeds, they can simply fight them in the way they have been taught or have learned how. Unfortunately the routinism of some physicians is on a plane little above that of the farmer's method; they are satisfied to live on without making any effort to find out and we do not look for any advance in learning from them.

The advent of the educated physician has already been referred to, so I shall proceed to give a few analogies between weeds and diseases. My remarks, as already mentioned, will be suggestive rather than exact scientific statements, mere outlines without dates. Of the many introduced diseases I can mention but a few. Animals and plants also have diseases but I shall refer only to disease in human beings.

ANALOGIES OF WEEDS AND DISEASES.

THE DAYS OF FEW WEEDS AND OF LITTLE DISEASE: The first settlers cultivated only small patches of ground, often only a "truck patch"; there were few kinds of weeds and these were natives and easily destroyed. The Ragweed (Ambrosia artemisiæfolia) was probably the chief among them.

Of the diseases of the native Indians at the time the white man first came among them, we know nothing, but we do know that their life was not conducive to the evolution and propagation and dissemination of diseases, and we can assume that, in all probability, they were practically free from disease. Men who live in isolation, and in proportion as they do live in isolation, are almost free from the common pus formers, the Staphylococci and Streptococci, with an absence of many of the common ailments of life dependent more or less on them.

The early settlers were a hardy set of men and women; they had left their weak and feeble behind, and they led a happy life, especially in the northern part of the State where the Indians were not savage or warlike, owing mainly to the influence of the French pioneers. There were few weeds and likewise few diseases; they had left both behind. But they found at least one native disease, namely milk sickness, or in other words, they found the cause of it, and when this got into the body, through the use of infected milk or the flesh of cattle with the trembles, a reaction came on, and this reaction was called Milk Sickness—a disease about which there has been much discussion.

THE DAYS OF DOG FENNEL AND JIMSON WEED—OF MALARIA AND TYPHOID FEVER: The Dog fennel came in early, from Europe. Jimson is a corruption of Jamestown, the early colonial settlement in Virginia. Both weeds flourish in neglected places, on farms, in villages and in towns; they disappear with the advance of progress and civilization. On clean farms and in clean villages and towns we see no Dog fennel today—but there are still Dog fennel towns in Indiana.

Malaria and Typhoid fever may appropriately be compared and contrasted with these two weeds; both were brought in by the white man. Malaria came first and was known as "The Fever." When typhoid fever came in it was called "Continued Fever," to distinguish it from malaria also known as "Periodical Fever." Until the decade 1840-1850, physicians the world over were not able to clearly differentiate typhoid fever, it was

long confused with typhus fever; very recently another disease has been differentiated, known as paratyphoid. Thus finer and finer distinctions are being made. In this connection I might refer to the analogous case of the plants Scrophularia nodosa, Scrophularia Marylandica, and Scrophularia leporella. and how the latter, a native Indiana plant, was for a long time confounded with the other, just as that in turn had been confused with the European form—a botanist will readily understand this simple allusion.

Malaria and typhoid fever both flourish under simple and primitive conditions, that is, under a neglect of sanitation. Malaria flourishes where the Anopheles mosquito breeds and is transferred from one individual to another by its bite. The drainage of wet places and the use of quinine are the chief factors that account for the subsidence of malaria and its present rarity. Typhoid fever differs markedly from malarial fever in that one attack protects the individual. The weak are killed off and those who survive are immune (second attacks of the disease being rare) and this fact has an important bearing. Typhoid fever is chiefly a water-borne disease, especially well water. Where wells and closets are close together or where the subsoil is porous, diffusion takes place. In a family where typhoid fever occurred there may be no further difficulty from the use of the well water, but any stranger or visitor using it may fall a victim. In cities dependent on wells there may be much typhoid fever, while on the other hand a city with a good municipal water supply, especially where the water is properly filtered, may have little of it. Cities dependent on a river supply without previous filtration may fare very well so long as the water is clear, but with the muddying of the river after a rain and with a resort of the citizens to the old wells, there may be a constant recurrence of the disease. In this connection we must not forget that many of our rivers are today nothing but open sewers full of infectious germs.

Malaria has disappeared from the cities (the Anopheles mosquito does not live in cities) but it still flourishes in backward, undrained, communities—communities that are still in the Dog fennel days. On the other hand, typhoid fever is all too common in some of our cities and towns—another indication of the survival of Dog fennel days.

Not so very long ago the chief diagnostic character for distinguishing between the two diseases was the fever, that is the elevation of temperature, but every now and then so-called atypical cases occurred which left

the diagnosis a matter of doubt. Today the scientific physician takes a few drops of blood from the finger of the patient, one drop he examines for the malarial parasite, the other is used for making the serum test for typhoid fever. In the one disease a few large doses of quinine usually cures outright; in the case of typhoid fever little medicine is given, little being required; with good nursing, proper diet, and an abundance of pure water and pure air, the patient is apt to recover. Although formerly no exact diagnosis was possible, yet the treatment of cases was simple; quinine, whisky, calomel and opium were standard remedies. Little attention was given to hygienic measures, the sickroom was often tightly closed, with the exclusion of fresh air, and as a consequence there was bronchial irritation, often bronchitis. Typhoid fever is not the fatal disease it was considered to be in the early days, and the nurse has largely taken the place of the doctor in the treatment.

In the early days of Indiana, bleeding was in order in the treatment of malaria, but this practice soon declined. Although the proper remedy is quinine, yet for a long time it was given in insufficient dosage. Just as too little water can be put on a fire, and fail to put it out, so too little quinine can be given to cure a patient—and if you wait too long the fire (or the disease) may become very destructive. It was customary to "prepare the patient for the quinine." Some died before the preparation was completed. The discovery of the Plasmodium malaria, the active cause of the disease, was a great advance in medicine. But to look for the parasite is not universal today; some physicians find it easier to prescribe before they are sure of the diagnosis—Dog fennel days still survive.

THE DAYS OF COMMON EUROPEAN WEEDS: The white man in his wanderings over the world has brought together a miscellaneous collection of weeds, and these follow him wherever he goes. Today most of our common Indiana weeds are immigrants from Europe, where they have resisted destruction for ages. The Amaranths and Chenopodiums when cut down will sprout anew; pulled up by the roots they take fresh hold while lying prostrate on the ground; if but a single plant ripen seed, the surrounding country will soon be restocked.

The white man in his wanderings has likewise collected a miscellaneous lot of diseases, and these, like his weeds, follow him wherever he goes. A list of their names may be found in the daily mortality statistics in the newspapers or in the advertisements of patent medicines.

Man fights his common diseases by resorting to the use of medicines, especially patent medicines; he has not yet learned that diseases, like weeds, may be eradicated, or that prevention is easier than cure. An intelligent farming community is apt to make a combined attack on weeds, and the less seed scattered about the fewer weeds there will be. Perhaps after a time we will go after diseases as the good farmer goes after his weeds; indeed, we have already reached the stage where we keep a lookout for such formidable diseases as the plague, cholera, typhus fever and several others; we do not allow them to land. But we are so accustomed to some diseases that have already landed and that have gotten a foothold among us, that we seem to have forgotten that we could get rid of them if we only tried.

Among the diseases once common in civilized Europe but now becoming more and more rare, may be mentioned leprosy, cholera, plague, typhus fever, miliary fever, scurvy, smallpox, malaria, typhoid fever, and others. Some countries are even beginning to show a reduction in the number of deaths from tuberculosis, and some cities regard the presence of much typhoid fever as a municipal disgrace. Man's control over the spread of diseases is becoming more and more marked.

The Analogy of Weeds and Diseases Carried Further: A botanist can take his manual and check off plants, especially weeds, that are spreading or migrating, and confidently look forward to the time when they will appear in his own locality. Those who are on the lookout for new weeds are rewarded every now and then by finding new arrivals. The date of many arrivals is known. New weeds are introduced in impure garden seed, or in the packing of crates or boxes; some travel by rail, others by water. Some come to stay for but a single season; they may find the environment unfavorable, early or late frosts may be detrimental; some live for a few years and then die out; a few, however, may find conditions favorable and flourish to such an extent that they may be seen everywhere, and a man who did not know of their introduction might be led to conclude that they always grew in the locality. The list of naturalized weeds in our State is today quite large.

The date of the first appearance of some of our diseases is likewise known, but unless a disease has some marked or striking characteristic, it is apt to be overlooked. Influenza and cholera were readily identified when they arrived in our State and the date of their arrival is duly recorded.

but tuberculosis and typhoid fever came in so quietly and unobtrusively that no notice was at first taken of them, at least we have no records of their first appearance. People ordinarily do not reason about these things, but the early Indiana doctors realized that a change was going on and long ago the Indiana State Medical Society had appointed a committee to look into the matter. (In this connection I may say that only last week I reported to the Cass County Medical Society a case of tropical sprue, or psilosis, brought into the State by a missionary returned from Korea. New cases are, however, not apt to arise from it.)

Although there is an analogy between weeds and diseases, the former growing in the earth, the latter on or in the body, yet diseases are not entities that can be handled and examined. But in the childhood of the race disease was held to be a thing that had gotten into the body, had taken possession of it, and the early medicine man tried to drive it out by the use of all sorts of noises and nauseous drugs, even by torture. The Chinese and Korean medicine men of today are quite expert in thrusting long needles into the body of the sick; it is really wonderful how little damage they do—they have learned how to avoid the vital spots or organs. In some other countries the sick are filled up with all sorts of nauseous drugs, and the physicians are quite skilled in knowing what to give so that the patient may not die from the effect of the supposed remedy.

A specific disease is now regarded in the light of a reaction of the organism, of the body, toward some foreign cause, the reaction depending on the kind of cause. The reaction may be so definite that the disease may be diagnosed from the symptoms alone, without examining into the nature of the cause, though diagnoses based on a recognition of the cause are of course more exact than when based on symptoms.

The classification of diseases a hundred years ago, at the time when our State was first being settled, was by classes, orders, genera and species, just as in the case of botany and zoology. Many systems of classification have appeared, each one supposed to be an improvement over preceding ones, and physicians are just now working upon a new system which they believe will stand the test of time. Old systems were based on symptoms. the new is based on the recognition of the cause of the disease. Thus Osler's recent treatise takes up first the diseases due to animal parasites—those due, in order, to protozoa, parasitic infusoria, to flukes, cestodes, nematodes, and so on—followed by the specific infectious diseases, from typhoid and typhus fever running down to tuberculosis and leprosy, in-

cluding some whose causes have not been definitely identified, analogy admitting their inclusion. The reactions or intoxications due to the ingestion of chemical substances, such as alcohol, morphia and lead, follow, with a mention of sunstroke—and then all at once there is a classification riot. For want of something better, a number of diseases are described under the head of "Constitutional Diseases." Then follow a host of affections and diseases that for convenience are grouped under their respective organs, beginning with the diseases of the mouth and running down the alimentary tract, followed by the affections of the other organic systems—the respiratory, the nervous, etc. One-third of the book is thus definite, based on a scientific system, the rest is simply based on convenience of reference. Although we have here real progress, yet how much still remains to be done.

Some of you may recall the story of the amateur botanist who complained to Linneus of the poverty of Sweden in material for study, and how Linneus placed his hand over a tuft of moss and said, "Here is study for a life-time." To study diseases we need not go to unexplored Africa, where so many new and strange diseases are being found; our common every-day ailments and affections and diseases are worthy of the deepest study, much is still to be learned about them. Not all is known about common everyday coughs and colds, about rheumatic and neuralgic aches and pains, about anemia and fever, dyspepsia and nervousness.

The old physicians diagnosed diseases almost wholly from or by their symptoms, and they were close observers, with sharpened senses like those of the Indian. The modern physician relies to a great extent on so-called laboratory methods, and the influence of the college and university laboratories is being felt. Rough and ready methods are more and more being replaced by refined ones. But we must not undervalue the importance of simple observations, without the use of instruments, nor should we neglect the training of the sense organs.

Scientific classifications are for scientific minds, but we must not forget that "Nature makes transitions and naturalists make divisions." Hair splitting in medical classifications, or nosology, is not unknown. As a matter of fact each group of specialists has its own system and nomenclature, and when the average all-round physician takes up one of the special treatises he requires the aid of a medical dictionary.

Popularly we can classify the diseases of our State, including those we have had in the past and not excluding those still to come, according

to the way in which they are transmitted from one individual to another. It is perhaps needless to say that diseases are carried from one individual to another, from host to host, much after the fashion of weeds carried from one field to another. The seed of a weed may gain access to a field by being blown in by the wind, or it may have been brought in by an animal, especially by birds; many weeds have been brought in by impure garden seeds. Cheat or chess among wheat means that the seed was present; it does not mean the transformation of one species into another, nor does it mean a spontaneous generation.

The railways are important factors in the distribution of weeds, as they are of diseases. Before the days of railways new diseases traveled slowly, cholera and influenza required a long time to encircle the globe in their early migrations; today diseases may spread rapidly. In a thinly settled country, weeds and diseases spread slowly, while the massing of people in cities, especially in the absence of sanitation, favors dissemination.

Diseases due to specific causes can be grouped in various ways, like weeds; whether native or foreign; whether coming to stay, or to disappear after a short time; whether spreading rapidly and then dying out, or spreading slowly but surely and permanently, etc. Looked at in this light we might regard Milk Sickness as a native disease which is disappearing; Cholera as a disease which has come in repeatedly but on account of unfavorable conditions never gained a permanent foothold; Malaria as spreading rapidly and lasting for a long time and then declining; Tuberculosis as coming in and spreading slowly but surely and not yet having reached its maximum among us. Measles, scarlet fever, smallpox, whooping cough, etc., need only be referred to.

Classification of Diseases According to Their Modes of Transmission: In a general way we may classify diseases according to how they are carried from one individual to another thus:

1. By direct contact—from one host to another.
2. Transmited through insects. (Notably malaria.)
3. Diseases conveyed by or through food.
4. Water-borne diseases.
5. Air and dust-borne diseases and affections (notably tuberculosis and pneumonia, with a host of other respiratory affections and a variety of aches and pains and functional disturbances.)

Out of the many diseases and affections that come under one or the other of the above groups, I desire to make mention of only two, namely, malaria, already referred to, and tuberculosis—one a decreasing, the other an increasing disease.

MALARIA: Malaria was the Grendel of the early Indianians. Today we can scarcely realize what the disease meant to the early settlers; in some localities it ravaged frightfully. Thus in the early history of our capital city we read that the forest was cleared in 1820 and lots laid out and in the spring of 1821 the immigrants rushed in to the number of six hundred or more. In the latter part of July malaria appeared, and, I quote from Drake, "Before the epidemic closed in October, nearly every person had been more or less indisposed, and seventy-two, or about an eighth of the population, had died." In some localities the disease was so severe that farming lands could not be sold, and for a long time immigration to our State was retarded; people went through to Illinois, to the prairies.

In an account of the diseases prevailing in Indiana in 1872, by Dr. Sutton, it was noted that the summer was dry, and in comparing reports from different counties of the State it was found that malaria had been more prevalent than usual in some of the rolling southern counties and in places along streams and rocky creeks, while, on the other hand, it was less common than usual in the northern counties where before it had been very common (but where drainage had made some of the worst places salubrious). At that time the view that decaying vegetation and moisture had a causative influence was universally believed, yet that theory did not explain the conditions. Today, in the light of the role the mosquito plays in the transmission of malaria, we can readily account for the facts.

In the rolling southern counties many of the small streams are fed by springs which flow a small volume at all times, but in dry seasons not sufficiently to create a current in the rocky creeks; hence many pools formed, and these pools served for breeding places for mosquitoes. Ordinarily even a small continuous current of water will prevent the development of mosquito eggs, and we must keep in mind the presence of fish and insects which feed on the mosquito larva, but which die off in times of low water, on account of its stagnacy. In the wet northern counties the drought meant a drying out of the breeding places of the mosquitoes, with a consequent reduction of the number of insects and of cases of malaria. The same reasoning holds for the increase of malaria along the larger streams; in ordinary stages of water there may be no stagnant pools

or isolated bayous, but such form in time of drought, resulting in a destruction of the minnows and the development of countless numbers of mosquitoes.

MOSQUITOES: Mosquitoes occurred in immense numbers in the early days, when breeding places were plentiful. They were common along the canals, and an English traveler on the Wabash canal, in 1851, writes of them: "After tea, we all began a most murderous attack upon the mosquitoes that swarmed on the windows and inside our berths, in expectation of feasting upon us as soon as we should go to bed. But those on which we made war, were soon replaced by others; and the more we killed, the more they seemed to come to be killed, like Mrs. Bond's ducks; it was as though they would defy us to exterminate the race. At last, we gave up the task as hopeless, and resigned ourselves, as well as we could, to pass a sleepless night." He adds: "What with turning about on account of the heat and trying to catch the mosquitoes, who bit us dreadfully, we did not get much rest; and we rose the next morning unrefreshed."

Canals were a factor in the mosquito-malaria problem. In some of the older States it was noticed that malaria followed the canals, that the disease appeared where it had formerly been unknown; in other places it markedly increased its prevalence; some towns were almost depopulated. When Indiana undertook to build canals the malaria question was not overlooked; there was opposition. The reservoirs were considered especially obnoxious, and in places, notably in Clay County, the people began to destroy them; State troops had to be called out to protect the embankments; the Legislature even appointed a committee to inquire into the matter and report. This commission, and medical men generally, tried to minimize the supposed evil influence; in the light of the then prevalent decaying-vegetation theory they could not see how canals or reservoirs could increase the disease. Today we can readily see that the popular belief rested on good foundation; the reservoirs and the small ponds made on account of the embankments at gulleys or ravines, formed breeding places for mosquitoes. The larger ponds in the course of time became inhabited by fish and thereby lost their mosquitoes, but in the smaller ponds with a periodical drying out, fish could not live.

It was noticed that canal-boat men suffered less from the disease than the people along the banks, and this at first sight seems difficult to explain. But the explanation is simple; it is analogous to the explanation of why railway conductors and porters seem healthy in spite of their exposure to

infective dust from the coaches, especially the smoking cars. On our railways today, men who are constantly suffering from the evil effects of inhaling a polluted atmosphere, manifested by colds and coughs, and catarrhs, by weeping eyes and noses, and are inclined to be sickly and demand frequent vacations, such men are not long retained in these positions by the railway managers—the weeding out process goes on all the time. Similarly a canal-boat man who was readily attacked by malaria and who lost much time on account of it, was not long retained in the position; those who retained their positions were the more resistent ones.

Facts are sometimes explainable by different theories. In the following story, taken from Drake, the substitution of "mosquitoes" for "whisky," as the apparent cause, more satisfactorily accounts for the facts or conditions. It should be remembered that the Anopheles mosquitoes are night-biters, that ordinarily they fly low, and do not frequent rooms or houses in which tobacco is smoked.

A few miles to the east of Fort Wayne there was a densely wooded swamp, known as the Maumee or Black Swamp, which extended on into Ohio. This swamp seems to have been salubrious; it was free from malaria, and families who settled in it "enjoyed uninterrupted autumnal health for three or four years," until malaria was brought in by other settlers. In 1838 excavations were made in the eastern end of this wet section for a canal. "The laborers, four or five hundred in number, were chiefly Irish, who generally lodged in temporary shanties, while some occupied bowers formed out of the green limbs of trees. * * * One contractor kept a liquor store, and sold whisky to all whom he employed, which was drank freely * * * the mortality (from malaria) among them was very great. Another lodged his operatives on straw beds, in the upper room of a large frame house, made them retire early, kept them from the use of whisky, and nearly all escaped the disease."

In this connection it may be said that in the malaria prophylaxis of Italy, screens on houses, and an avoidance of the mosquitoes outside of the houses, are of the greatest importance. In our own country the use of screens in windows and doors is a most important factor in the diminution of many ailments and diseases that formerly prevailed during the time of mosquitoes and flies, cholera infantum not the least among them.

The belief in the injuriousness of night air, still so prevalent among us, is readily traced to the days of the night-biting Anopheles mosquitoes filled with the germs of malaria. These mosquitoes do not live in cities, or

at most only in the outskirts, and city night air is really better than that of the day time, because there is less dust in it.

The widespread use of quinine today is also traceable to the days of much malaria. Then it was given in almost every case of sickness, a sort of panacea, and this practice is simply kept up, not only by the people but by many doctors. Today quinine really has a very limited use. The so-called "False malaria" of our cities has no relationship to malaria proper; it is simply a reaction due to bad air, and not to the plasmodium malaria.

In the early days, when there was but little quinine, and that high priced, many of the native barks and herbs were used, notably the Dogwood, Yellow Poplar, Wild Cherry, Thoroughwort and American Centaury. They were steeped in whisky and formed "bitters;" bitters still survive and some are widely advertised in the newspapers; as a rule their value is nil. A number of other things concerning malaria might be mentioned, but I must desist and will close this account with a few remarks on Adaptation and Immunity.

We know that plants and animals are adapted to their surroundings and that few can bear any marked change of environment; wet soil and dry soil plants can not exchange places, nor can tropical animals exchange places with those of the frigid zones. But many of our cultivated plants and animals have been shifted about so much that they are able to flourish under a variety of surroundings, just as the white man flourishes because he has had such a varied experience in the past. Now there is also an adaptation in the case of diseases. Where a disease has long been in a country or locality, there is a mutual adaptation between the disease and the people, or in other words, between the parasite and the host. If a disease is so virulent that it kills off all the people, then the disease in turn is killed off, or dies out, for want of material. If on the other hand, a disease is not strong enough to attack at least some members of a community, then it is apt to be mild and to pick out and live only on the weak and feeble or aged or the very young, the robust adults escaping. But where a disease gets among a people who have never had it then it may be very destructive, many may perish and few survive, but the survivors may re-people the territory with a stock less susceptible, and we can see how, in the course of ages, with a killing off or weeding out of the susceptible, a strain may be produced that is able to live in the presence of the disease.

Examined in this light we get some clew to the original home of malaria. The negro of Africa is quite immune against malaria; there is an

## MALARIA IN INDIANA.

Primeval conditions.

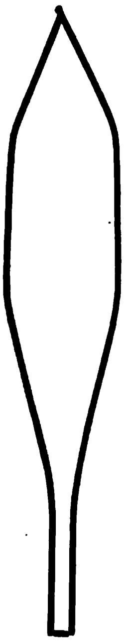
Ground covered by forest or herbage, retention of moisture or rain.

Streams running, clear, full of fish.

Coming in of the settlers.

Destruction of the forest, periodical drying up of the small streams.

Destruction of fish, increase of mosquitoes.



Advent of malaria.

Absence of physicians and remedies—antiperiodics.

Settling up of the country, malarial parasite more readily transferred.

Canal reservoirs and railway embankment ponds as factors.

Drainage of wet places, fewer mosquitoes.

Free use of quinine.

Isolation of the sick and use of screens.

Subsidence of malaria.

No malaria in large cities, little in suburbs.

Continuance of malaria in backward communities.

adaptation. The disease producing agent, the plasmodium, is there, and has been found in the blood of the people without apparently doing much harm, but when a white man gets into the country he may succumb very quickly. There may be even a marked difference in white men in their susceptibility to malaria, or other diseases, doubtless depending on the exposure of the ancestors in former times. The susceptibility of our native Indians is one of the chief arguments against the indigenous origin of malaria.

Malaria in Indiana has about run its course, as it has in older civilized countries; its mortality today is slight—our dog fennel days of malaria are about over.

TUBERCULOSIS: If malaria was the Grendel of early Indiana, tuberculsis occupies that position in our State today. While there has been a steady decrease in mortality from malaria, there has been a steady increase in mortality from tuberculosis, and we have not yet reached the maximum. Tuberculosis is an air-borne disease, or, more strictly speaking, a dust-borne disease, and conditions in our State were never so bad as today. Although the mortality statistics of tuberculosis are a fair index of bad air conditions, they do not tell the whole truth; the deaths from a number of other affections must be included, notably those from pneumonia.

Tuberculosis is the slow protest of nature against bad air conditions, pneumonia is the sudden outcry. The approach of tuberculosis is heralded by many and repeated warnings—clinicians speak of a pre-tubercular stage, a stage of coughs and colds, of pains and aches. Pneumonia strikes suddenly, without warning. The stranger within the gates of the city has no time to flee; and to remain in the crowded city is too often synonymous with death. In the country where air conditions are good, pneumonia is neither frequent nor very fatal, and under good air conditions tuberculosis does not thrive at all; indeed, the city victim on going out into good air is apt to recover, if he goes in time. The ancient Greeks knew the value of good air, the ponderous volumes of the physicians of a hundred years ago testify to its value, a value which we are now but rediscovering—we do not yet fully appreciate it.

We as a matter of course look upon tuberculosis as the great enemy of the human race—but after all it may be a friend in disguise! Few may be able to look at it in that light, but some arguments may be made in support of such a statement.

The old herbalists believed that the Creator made no plant in vain; they believed that every plant had its uses, if we could only find it out. Looked at in this light the lowly plants that produce disease may have some use; the cholera bacillus teaches our cities to clean up, and in proportion as they clean up they escape the ravages of the disease. The typhoid bacillus teaches us to look after the purity of our water supply, and cities and individuals who heed the lesson escape the disease. Perhaps the tubercle bacillus may teach us to clean up our cities and our homes and meeting places; it may teach us the use of pure air. But if tuberculosis is a friend of the race, it needs watching as fire needs watching; like it, it may be an exceedingly bad master.

We must look at the pre-tubercular stage in the light of a warning to get out of the dusty and smoky city; the aches and pains and the coughs and colds may subside very promptly in good air. If the individual remains in the city the disease sets in in earnest, to attack the lungs, and then it generates hope, and the victim wants to be up and about. And he should heed the additional warning before it is too late; he should not lie about the house or the dusty city; he should go out into "God's green country" and into the sunshine and pure air.

When a man has an acute alimentary tract affection, not to say disease, nature takes away his appetite and makes him gloomy; he lies about and refuses food, thus imitating the lower animals; if he persists in eating she sends a violent pain and he will probably desist. Nature wants no food and no work to do with an impaired alimentary tract; she wants rest, just as a broken bone wants rest to repair the damage. Men who heed the warnings of nature, the little aches and pains that tell them to do this and avoid that, are apt to live longest; the chronic invalid who takes care of himself may live on to old age, while the so-called strong or robust man who never has an ache or a pain, no warnings from nature, may go to pieces all at once and prematurely.

The aches and pains of the pre-tubercular stage of consumption should be heeded, and the hope generated by the disease itself should be acted upon; nature is showing the way. The elimination of the imprudent, and of those not adapted to their surroundings, has been going on for countless ages. Diseases have killed off our weak, and the process still continues. Our Indians scarcely came within the range of disease elimination; their life was not conducive to the propagation of diseases, certainly not of tuberculosis. When the white man brought in tuberculosis the Indian was

scarcely attacked so long as he lived under old time conditions, an active out-door life; but when he tried to live under white man's conditions, in a fixed home, he promptly began to fail and is still failing—just as the negro fails when he crowds into the cities, and as the Italian fails who comes to our cities from the pure air of his mountain home. We may say the Italian is degenerate, that he has no stamina, but that does not explain his susceptibility, no more than to say the Chinaman is degenerate because he can live under filth conditions that the white man can not bear. The Jews coming from the old European cities, where their ancestors have for a long time lived in the ghettos and under extremely unsanitary conditions, are quite resistent to attacks of tuberculosis; they are simply the survival of the fittest; the Jew whose ancestry goes back to the open country, to a pure air life, can not hold up alongside the other, for his ancestors have not undergone the elimination process.

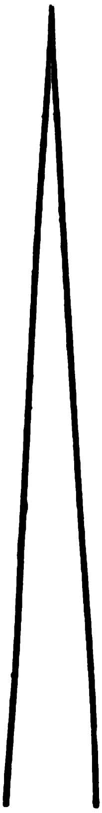
Tuberculosis is a protest against bad air conditions. We ought to be the healthiest and strongest people on the face of the earth; land is abundant and fertile, we have no years of famine, men are not tied down as in the old world; the poor food of Europe and the long hours of toil are unknown among us; at least there is no valid reason why long hours should be required. In spite of these conditions tuberculosis is on the increase among us, whereas in some European cities there is a decrease. Why should this be so?

If we write out statements of conditions, one line for clean European cities and another line for American city conditions, and make an equation by canceling conditions that equal each other, we have left the polluted air condition or factor; it offsets all our advantages.

Many individuals can thrive in the air of our cities today, others fail; thousands fail every year. Many contract the disease in the city and go to the country to die; many die from city diseases, other than tuberculosis and pneumonia, traceable to bad air conditions.

Shall we let bad air conditions go on, or even get worse, as they seem to be doing, and shall we let countless thousands die in the unceasing process of adaptation to environment, or shall we attempt to modify the abnormal environment and allow these thousands to live? We are told that tuberculosis is a curable disease, and that it is a preventable disease. It is an introduced disease which we have allowed to flourish unhindered. It is a disease that flourishes only under certain surroundings. We can make

## TUBERCULOSIS IN INDIANA.



Primeval conditions.

Ground covered by vegetation—no dust. Indian had no name for dust.

Outdoor life not conducive to the propagation of tuberculosis.

Coming in of the white man, minus his weak, feeble and sick.

Clearing of the ground, formation of dust; Indian applied name of ashes to it.

Building of cabins and houses, formation of house dust.

Coming in of the feeble and sick; cared for in houses.

Advent of tuberculosis.—Tubercle bacillus.

Tuberculosis picking out the weak and those living indoors.

Settling up of the country, building of roads—formation of road dust.

Villages as factors, increased facilities for distributing the disease.

The village store, farmers crowded about the stove in winter, a factor.

Schools, churches, meeting halls, factors in polluted air.

Development of the tobacco chewing habit, an important factor —spitting.

Development of town conditions, shops and trades, confinement of men indoors.

Coming of the railroads and filthy cars and plush seats.

Development of city conditions—city dust.

Smoke from coal; paved streets and sidewalk dust.

Street cars as factors, crowding and bad air.

Tenements and flats, poor ventilation and little sunlight.

The trailing dress an important factor, filth dragged into the home.

Advent of the city slums, increase of poverty and neglect.

Blunting of sensibilities by the use of alcohol, opiates and anodynes.

Continued increase of tuberculosis.

these surroundings unfavorable for the disease; but it takes a combined effort, the individual is powerless.

Malaria is disappearing because the conditions favorable for its existence are disappearing; the opposite is true of tuberculosis. Moreover, quinine both prevents and cures malaria, and pure air prevents and cures tuberculosis. Whisky and calomel were popular prescriptions for malaria, neither cured; whisky and cod liver oil are popular prescriptions for tuberculosis today, yet neither cure, neither singly nor combined.

The administration of whisky, or of alcohol in any form, may be followed by a sense of well-being in tuberculosis, and in dust infection generally, and that is the reason why alcoholic preparations are so popular and so widely advertised as cures. But the sense of well-being is a false sense of security; to benumb the body and reduce the pain, the pain by which nature warns us, is poor treatment. As a matter of fact, alcohol is still one of the great eliminators of the human race; if we are wise we will avoid using it.

Over fifty years ago one of the pioneer physicians of Eastern Indiana wrote of the changes he had observed in his community and in the State; he said: "Phthisis, pneumonia and bronchitis are believed to be on the increase. Whether this is due, in any degree, to improved modes of living, such as tight houses, the general use of stoves, a less constant exercise in the open air, etc., it would be interesting to know." Today we know. Fifty years ago conditions in Indiana were quite primitive compared with conditions seen in our cities today, and yet the gradual increase of dust diseases was being noticed. (Tuberculosis in Indiana, page 45.)

(The chart of the evolution of different kinds of dust will explain itself.) (Dust chart, page 47.)

Tuberculosis, known also as phthisis and consumption, is among us; it came in with other diseases; it came in like some of the weeds of the fields. How soon will we make any attempt to get rid of it?

Our State Board of Health has been and is an important agent in diffusing a knowledge of diseases and of disease prevention among our people, and the recent establishment of laboratories for identifying diseases and for testing the purity of foods and drinks is of the greatest importance.

Physicians have been the prime movers in the establishment of these evidences of civilization, but it has been a long fight.

I am glad to see several papers on the program of our Academy this year that bear on the subject of sanitation; there have been some in the

## THE EVOLUTION OF DUST.

| | | |
|---|---|---|
| | Cosmic Dust. | |
| | Volcanic Dust. | |
| ABSENCE OF MAN. | Desert Dust. | |
| | Plant Pollen Dust. | |
| | Wild Animal Trail Dust. | |
| HUNTING AND FISHING STAGE. (All men alike) | Traces of Dust due to Man. | Age of neglect of the Feeble. Aged and Sick. |
| PASTORAL STAGE. | Domestic Animal Dust. | |
| | Dust in Tents. | |
| AGRICULTURAL STAGE. | House Dust. | Origin of House Diseases. Case taken of the weak, aged and sick; |
| | Country Path or Road Dust. | Greater development of Parasitism. |
| | Village Street Dust. | |
| HANDICRAFT STAGE. | Shop Dust. | Employment of the feeble in shops. Rapid development of air-borne diseases. |
| | Shop Dust with Spittle. | Homes for the aged and feeble. Free use of alcohol. |
| | Paved Street Dust. | |
| INDUSTRIAL STAGE. | Factory Dust in variety. | Large factories; crowded tenements; dusty and smoky air. |
| | Sidewalk Dust mixed with Spittle. | The age of hospitals and dispensaries, of throat and chest disease specialists. |
| | Tobacco Juice Dust. | |
| | Trailing Dress Dust. | No pure air in large cities. |

past, and I hope to see more in the future; perhaps they could be grouped under a separate head, that of Sanitary Science.

Our Academy has a committee on "Legislation for the Restriction of Weeds." The popular conception of a weed is, a plant growing in the garden or field or meadow, of a plant out of place and more or less resisting destruction at the hands of man. That some plants grow on and in the human body, and in animals as well, is not so well known. The thought has suggested itself: Perhaps the scope of this committee could be enlarged by taking account of the minute weeds of the body. I would like to see the title of this committee read "Legislation for the Restriction of Weeds and Diseases."*

## STATE HOSPITAL FOR TUBERCULOSIS.

In conclusion I desire to make a few remarks concerning the establishment of a State institution for the treatment of tuberculosis.

Modern medicine concerns itself more and more with disease prevention, in the individual and in the community. To give relief from disease and affliction has always been the aim and the practice of the physician, but so long as the active causes of diseases and the modes of their transmission were unknown, little could be done in disease prevention. The good Samaritan still has a place, but the physician who today is only a Samaritan in binding up wounds and who makes no effort to prevent the infliction of wounds, or who treats diseases and makes no effort to prevent the propagation of diseases,—such a physician does not fully represent modern medicine.

Modern medicine knows much about disease prevention, if the knowledge were only applied. Intelligence counts for much. The intelligent of a community often avoid much sickness, whereas the ignorant suffer; some of the latter are kept in a state of poverty on account of their lack of knowledge of diseases and disease prevention. As people become better educated in sanitary science and in hygiene, they will require more of their physicians. The high school graduate who has studied the human body in health and in disease is not apt to be a purchaser of quack medicines, or to consult an ignorant physician, much less one who has to herald his ac-

*On the day following this suggestion, the chairman of the above committee made a motion to enlarge this committee by adding two men who are physicians and changing the title as suggested; the motion was carried without a dissenting voice.

complishments in advertisements in the newspapers. Much is to be expected from the teaching of sanitary science in our schools.

Since it was discovered that tuberculosis is a curable disease, a number of countries and States have established institutions where such sick can be treated. Germany leads in this work. Some of the institutions are tent colonies in the forests. Out-of-door life, plain food and drink, pure air, little or no medicine, that is all that is required. The nostrums advertised in the newspapers are of no value. Nature simply needs a chance to correct the difficulty. When the disease has once fully taken hold, little is to be expected from any form of treatment, and only too often the real nature of the disease is not recognized until it is too late. It is possible to recognize the early stages of tuberculosis, and that is the time for beginning treatment; beginning in the pre-tubercular stage is still better. With flames bursting from every window, we do not look for the firemen to save the building, but we rather expect it of them when they arrive at the stage of much smoke and a tiny flame.

There are at least 25,000 individuals afflicted with tuberculosis in our State today, and 5,000 die annually in Indiana from this disease; in addition many die from pneumonia and other respiratory diseases, and of affections dependent on a polluted atmosphere. Shall we imitate Germany and a number of our sister States and attempt to save these lives, or shall we let disease elimination go on unhindered? Sooner or later the process of elimination will reach our own families, it may reach us individually.

But, you may say, it will require an immense institution to take care of so many sick. So it would if all were to be admitted, but we can at once exclude those who are mortally ill and who can not recover, and if we also exclude those who are able to pay for treatment at a private institution, the number would be considerably reduced. We need scarcely consider the argument that if the State allows its citizens to get sick from preventable disease, it should also take care of those sick.

As a matter of fact many institutions, even State institutions, can not take care of more than a hundred, or at most a few hundred of the acutely sick. What then, you say, is the use of attempting to save the few and let the many perish? That is one way of looking at it. But if we look at a State Hospital as being a school for missionaries in the cause of pure air and right living, we get a different conception of the problem. It is not a question of saving a few out of the many lives now going to waste and

leaving behind a trial of desolution, but it is a question of trying to bring about a change, in arresting the increase of the disease in our State. Every man and every woman who returns from such an institution would be a missionary in the cause of pure air and right living—and we need such missionaries more than do the heathen.

# A State Natural Park.

Fred J. Breeze.

Primeval Indiana has passed away. The great forest-covered plains are now bare, and divided into cultivated fields. The wild animals, like the bison, bear and deer, have gone with the forests; while numerous species of birds and other small animals have also disappeared. Our streams have lost their purity and wild beauty; some have been fouled with sewage, while others have been dredged and straightened into artificial drainage channels. Thousands of marshes and hundreds of lakes have been drained, and cultivation of the soil has destroyed thousands of the smaller forms of plant life.

Not all of these changes are desirable, neither are they all necessary, yet the destruction of natural features will continue; and it seems that the time is not far away when Indiana will be nothing but a vast expanse of farms and cities, and man, having humanized everything, will be surrounded by a surfeit of artificial features, the only fauna and flora being the domestic animals and plants.

Some intelligent work ought to be done to stop the useless destruction of the wild forms of nature. Many natural conditions still existing ought to be preserved, and others now gone but still redeemable ought to be restored before it is too late. Every farm has some little corner of ground which is not tillable and this should be given over to nature. Here, trees, shrubs and flowers may grow in freedom, and birds and small ground animals find safe retreat. Every county should have a small reserve or natural park. Such an area could well serve as a small forest reservation, as well as a place where a rich plant and animal life could safely exist.

But to maintain an area in which natural or primitive conditions could exist on a sufficiently large scale we need a natural park under the control of the State. It should be several square miles in area, and should be in the northern part of the State, so that it might include a lake within its limits. Its size and shape should make it possible not only to have a lake, but a stream basin drained by the lake. Into this park should be placed the wild animals that formerly lived in this State. Here animals

and plants could live under perfectly natural conditions. The park could serve for many scientific purposes. In it the Department of Fisheries and Game could carry on experiments in fish and game culture. After a few years it would be the best possible place for a Biological Station. It would also be just the place for the field meetings of the Academy of Science. It is not necessary at this time to go into details concerning its character, management, and purposes, but only to suggest a few of these things.

Such a reserve would be a little part of the "Indiana of Nature" preserved for the pleasure and profit of the people for all time to come. If the members of the Academy become convinced of its value and will co-operate to educate public opinion toward this end, a State Natural Park càn be secured within the next decade.

# The Drainage Area of the East Fork of White River.

Charles W. Shannon.

"Every river appears to consist of a main trunk, fed from a variety of branches, each running in a valley proportioned to its size, and all of them together forming a system of valleys, communicating with one another, and having such a nice adjustment to their declivities that none of them join the principal valley either at too high or too low a level, a circumstance which would be infinitely improbable if each of these valleys were not the work of the streams flowing through them."*

Streams are among the most important agencies which give form and expression to the surface of the land. The study of streams, therefore, involves to a great extent the consideration of the nature and origin of many topographic forms—hills and mountains, plains and valleys—and the changes they pass through.

Every person is familiar with the manner in which the rainwater that falls is gathered into rills, rivulets and brooks, which unite to form larger rivers. Every one is aware, also, that streams are turbid after heavy rain. Yet comparatively few people have thought of the work and change upon the surface of the land which is done by even the smallest of the rills and all along the course of the river; nor have they thought that the smallest rill down the hill slope or along the roadside is adding to the work of the large streams, or adding to the extent of the drainage area of the stream.

The drainage area of a stream is the land area which is drained by the main stream and all its tributaries—and the tributaries of the tributaries.

The drainage area of the East Fork of White River is composed of the western central and southern part of Indiana, including the greater part of twenty-five of the ninety-two counties of the State, and a total of about 7,000 square miles, or a little less than one-fifth of the total area of Indiana. This area is mapped out in full on the accompanying map, with the exception of a few counties lying to the north of the area shown.

*Illustrations of the Huttionian Theory of the Earth; by John Playfair.

The geological conditions of the country greatly influence the course and action of streams. The heavy curved line across the map represents the southern limit of the ice sheet. Thus this drainage area is partly in the glaciated and partly in the unglaciated portion of the State. It is in the unglaciated region that we have the most picturesque scenery. The entire area, subjected to the processes of weathering and stream erosion for millions of years, was maturely dissected into a complex network of valleys, ridges and isolated hills. Over this surface the ice-sheet passed several times, extending as far as the boundary shown. Its effect was to smooth off the hills, fill up the valleys and to leave the surface covered over with a great mass of loose, foreign material from the northern regions. Since glacial times the streams have to some extent removed the loose material from some of the old valleys and are forming a system of new drainage in the surface of the drift. Geologically speaking, this glacial accumulation is of very recent origin and the streams seem to have made only a small beginning in the work they will be able to perform.

An accurate topographic map of the drainage area would show the contrast in the physical features of the glaciated and unglaciated portions better than any other description or illustration that could be given to a person who had not been over the area to investigate the contrast. In the glaciated area the contour lines would run in large regular curves and far apart, showing the smoothness and regularity of the surface. South of the drift limit the lines would be very close together, with a very winding course and sharp curves, showing a region of deep, narrow valleys, irregular divides and abrupt cliffs.

In attempting to work out the geographic history of an area whose drainage has been arrested by the invasion of an ice-sheet, we find that the story of the life resolves itself into four fundamental parts. First: What are the topographic characteristics of the area during the preglacial history. Second: What changes took place during the glacial history. Third: What has happened since the disappearance of the ice-sheet; its post-glacial history. Fourth: What was the effect produced by the above events on the unglaciated parts of the area.

It is doubtful if the entire glacial area in Indiana was covered by the ice-sheet at any one time. At its extreme limit the ice deposited but little drift; and as a rule there is not a well-defined ridge of drift along the glacial boundary, though some drift is to be seen—as in Chestnut Ridge, in Jackson County, and a similar ridge in southern Morgan County.

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From the east border of the river, a few miles below Columbus, northeastward to Whitewater valley, in southern Fayette County, there is a well-defined ridging of drift standing twenty to forty feet above the border tracts. Upon crossing Whitewater, the border leads southeastward and is not so well defined as west of the river, though there is usually a ridge about twenty feet high.

From the north line of Jackson County, following the boundary around to the west and south, it is in many places hard to trace as a well-defined line. The ice-sheet must have been very thin, since the topography shows little, if any, modification. In many places, however, heavy beds of gravel and till lie against the hill slopes to the north and east. Many large granite bowlders are also piled up along the hillsides and scattered along the streams. In this area in the counties of Hendricks, Rush, Johnson, Shelby, Henry, Decatur and Randolph, there is a form of moraine known as "bowlder belts," long, narrow, curving strips of country, thickly covered with large bowlders. Low, winding ridges of sand and gravel parallel to the ice movement mark the course of a sub-glacial drainage through Madison, Hancock, Shelby and Bartholomew counties. The longest glacial drainage channel in the State extends from Grant County to White River, in Bartholomew, but it is not now occupied by any one continuous stream. Most of the streams in the glacial area are known as sand and gravel streams and afford great quantities of sand of economic importance and an abundance of gravel suitable for road material and ballast. In several of the counties are overwash aprons in which the sand and gravel are spread out over broad areas.

The thickness of the drift over the State varies greatly, the greatest thickness in the State being about 500 feet. While in this area the drift would be from 50 to 100 feet, there is on the higher points but a thin coating, but the filled valleys make a higher average. It is the glaciated part of the area that is of importance from an agricultural standpoint. The glacial drift is a very productive and permanent soil, and can not be surpassed in the production of the cereals, while the bluffs, knobs and hills of the driftless area are proving to be favorable for the growing of fruits.

The rocks of the State are all sedimentary, and in the area here discussed were laid down upon the bed of a shallow sea receding to the southwest. Thus the strata dip gently to the southwest, at the rate of about 20 to 40 feet to the mile.

In the State there are six different geological periods represented—the

Pleistocene (no rock outcrop), the Coal Measures, the lower Carboniferous or Mississippian, the Devonian, the Silurian, and the Ordivician or lower Silurian. All of these are found in the territory of this drainage area; and of the twenty-five or more formations as subdivisions of the above-named periods there are at least eighteen of these found as surface outcrops in this area. These formations may be listed as follows: *Merom Sandstone.*—A massive coarse-grained sandstone lying unconformably on the coal measures. It furnishes glass-sand and some building stone. *Mansfield Sandstone,* the basal member of the coal measures, is a medium to coarse-grained stone. It is quarried for building purposes and for whetstones and grindstones. *Coal.*—This area is just in the edge of the Indiana coal field. The coal is, therefore, very thin-bedded and is mined only by drifting. *Shales.*—The shales of the coal measures are in many places from 25 to 40 feet in thickness, and are of value in the manufacture of cement, paving brick and sewer tile. Associated with these shales in Martin, Greene, Lawrence and Orange counties are considerable deposits or iron ore; there are also beds of fireclay underlying the coal. *Huron.*—This consists of a series of thin bedded limestones separated from each other by shales and sandstones. *Mitchell Limestone* consists of massive compact layers of dark blue and gray limestone with interbedded impure fossiliferous limestone, shales and chert. *Salem Oolitic Limestone.*—The massive fine-grained stone so well known as a building and ornamental stone. *Harrodsburg Limestone.*—A very fossiliferous limestone, and also contains great numbers of geodes and chert in the lower members. *Knobstone.*—A series of shales and sandstones reaching a thickness of more than 500 feet. This formation has its western outcrop in the eastern half of Monroe and Lawrence and extends to the east as the surface stone for many miles. To the present time but little use has been made of this group, but it is growing to be of economic importance. *New Albany Shale.*—A persistent underlying brown to black shale at the top of the Devonian System. It is rich in bitumen and when kindled will burn. The laminated structure and joints are shown in the illustration. *Hamilton Group.*—The Sellersburg and Silver Creek limestones. The former is a white to gray limestone, rather thin bedded but persistent, stretching from the Falls of the Ohio, north through Clark, Scott, Jefferson, Jennings and Decatur counties. The Silver Creek lies beneath the Sellersburg. It ranges in thickness from 15 to 16 feet in the Silver Creek region to 5 or 6 feet in the vicinity of Lexington, in Scott County, and disappears altogether as a per-

sistent formation in the northern part of the same county. *Niagara Group.*—The member of the group found in this region, is a soft, massive, buff, sub-crystalline to a bluish-green, shaly, limestone, with a characteristic bed of bluish-green shale several feet thick at the base of the formation. *Pleistocene.*—The area deeply covered with glacial drift and having no rock outcrop.

*Triassic to Tertiary, Inclusive.*—"The only deposits of these ages known (with the possible exception of the Merom Sandstone) are some gravels found on certain high ridges in Martin and Perry counties, and possibly elsewhere. These are outside the drift area, and above any known stream deposits of gravel. Taken in connection with the uniformity of elevation reached by the highest hills, in the Mansfield sandstone area, the Knobstone area and the Silurian area in the southern part of the State, it has been suggested by Mr. Frank Leverett of the United States Geological Survey, that at least southern Indiana was reduced to base level in Tertiary times. In that case the present and pre-glacial topography of Indiana would date from some time in the Tertiary. This Tertiary erosion might also account for the absence of cretaceous deposits, if any such were ever laid down in the State. Until more study shall have been given these gravels and their interpretation, the matter of this paragraph must be considered more as a suggestion than as a demonstrated fact."* (See Report State Geologist 1872, p. 138; 1897, p. 22.)

The highest point in the State is in the southern part of Randolph County, which at the highest level is about 1,285 feet above sea level. It is on this height of land that both the East and West forks of White River have their source. The C., C., C. & St. L. R. R. (Peoria Div.) passes along this divide between the head waters of these streams. The West Fork increases in volume and velocity more rapidly than the East Fork, which reaches its destination by a very winding course. Its length is greatly increased and its slope decreased by its numerous meanders, but it is still a moderately swift stream. After reaching the unglaciated area the direction of the stream is greatly influenced by the joint planes in the geological formations. The main streams of these forks grow farther apart until they reach Shelby and Marion counties, where they approach each other,

NOTE.—For description, composition, structure, extent, uses, etc., of the various formations named above, see Thompson, 17th Ann. Rep., pp. 30-40; Hopkins, 20th Ann. Rep., 1895, pp. 188-323; Kindle, 29th Ann. Rep., pp. 329-368; Hopkins and Siebenthal 21st Ann. Rep., 1896, pp. 291-427; Blatchley 22d Ann. Rep., 1897, pp. 1-23; Ashley 23d Ann. Rep., 1898; Siebenthal 25th Ann. Rept., 1900, pp. 330-39; 30th Ann. Rep., 1905; E. R. Cumings, in Pro. Ind. Academy of Science, 1905, pp. 85-100.

then again turn from one another until, in the western part of Lawrence and Martin counties, they come nearer and at the southwestern corner of Daviess County are united in one stream at an elevation of about 425 feet. Both forks are fed by numerous tributaries, which produce an intricate drainage system. In many places the heads of these tributaries approach each other very closely and have in some cases resorted to piracy. It is obvious from the varying character of the valleys and the terraces which border them, that both forks suffered many disturbances during the glacial period. As has been stated, we know that valleys have been excavated by the streams flowing through them, and it is also true that the terraces beautifying their sides are in most cases due to the same agencies—that is, terraces owe their origin to the processes of corrosion, or of deposition, or to both. Many of the terraces are due principally to the re-excavation of preglacial valleys. In much of the unglaciated area there are marks of several well-defined drainage levels. The region ranges in elevation from 150 to 300 feet; the streams cut down rapidly from the upland, then run off with a slight gradient through deep valleys with rather flat and comparatively wide bottoms and very steep sides, with stepped and sloping terraces with gracefully bending curves which add much to the attractiveness of the valleys. The upper terraces are formed by the streams cutting down through the formations of the original table-lands. The lower terraces are composed of mixed materials of the higher levels. The best examples of these terraces are in the Salt Creek and Clear Creek valleys, and in the principal valley of the main East Fork and its adjacent side valleys. Some of these terraces are shown in the illustrations.

This entire drainage area affords much for interesting study and exploration, but, as stated above, it is in the unglaciated portion that is found the most picturesque scenery. The diversified physical features produced by the processes of erosion and the weathering of the various geological formations give a region of rugged and beautiful scenery. Some of the characteristic and marked scenic points are described below.

"Weed Patch Hill," in Brown County, is a high ridge in the Knobstone, forming the divide between two of the main branches of Salt Creek. At its highest point it is a little more than 1,000 feet in elevation. One of the illustrations gives a view looking northwest from this elevation and gives an idea of the Knob topography. "Guinea Hills" is a ridge rising to a considerable elevation, extending in a northeast and southwest direction through the southwest part of Scott and the northwest part of Clark coun-

ties. These hills form the divide between the tributaries of the Muscatatuck, one of the chief branches of the East Fork, and the headwaters of Silver Creek, which flows south into the Ohio. It is interesting here to note that water falling on the high bluffs of the Ohio near Hanover, and to the north within one mile of the river, does not there flow into the Ohio, but finds its way into the Muscatatuck and the East Fork, and after covering a distance of more than 300 miles flows into the Ohio at the southwestern corner of Indiana. The "Haystacks" are conical shaped hills which, seen from a distance, have the appearance of haystacks; these are plentiful in the central part of Lawrence County. "Rock Houses" are large openings between and under large rock masses due to undercutting and the breaking off and tilting of the rocks. "Honeycombs" are rock surfaces in which the softer parts have been weathered out, giving a porous, honeycombed appearance. These are found in the region of the Oolitic Limestone and the Mansfield Sandstone. One of the most interesting spots to visit is the "Pinnacle," near the town of Shoals, the county seat of Martin County. Here a high ridge of Mansfield Sandstone, one hundred ninety-six feet above the level of the stream, terminates abruptly within a few yards of White River. Large masses of rock that have broken off, lie around the foot of the ridge in every position. From this point one obtains a good view of the character of the topography of this region. To the northwest of this ridge the formations have been cut through by disintegrating forces, and there has been left standing at some distance from the head of the ravine a tall mass of sandstone, which has received the name of "Jug Rock," from the fancied resemblance to an old-fashioned jug. On the upper side it is forty-five feet high and on the down-hill side, seventy feet high; it is capped with a flat projected layer of harder sandstone. At the south of the deep-wooded ravine is the "Glen," an under-cut sandstone cliff with an intermittent cascade. Across a valley to the north is "House Rock," a large sandstone cave, the entrance to which is about thirty-five feet high, and the main room, with an opening in the top, is very much higher. It is formed principally by the tilting of large rock masses. The sandstone in front of the cave is weathered into an elaborate fretwork. Other points of interest as one goes down along the river are the "Acoustic Rock," "Buzzard's Roost," "Hanging Rock," "Kitchen-middings," "Shellbank," and the "Hindostan Falls."

In Washington, Lawrence, Orange and Monroe counties the subterranean drainage has an important place. The ground water working along

the point planes and on the more soluble parts of the limestones has produced a great variety of sink-holes, caves and "lost rivers." The sink-holes are basin shaped depressions many feet deep, and often hundreds of feet in diameter, with an opening at the bottom which leads into some underground channel; in some cases the openings have become filled and the water is held in the basin. In many places a stream runs into these holes, then by underground passages for a great distance, and again comes to the surface in the form of springs. Valleys, sometimes two to four miles in length, are drained through underground channels. This gives rise to a confusing system of hills and valleys, though a well-defined drainage may be worked out which in itself is usually made up of sink-holes. There are many pure water springs in this region and also many springs of mineral waters. The best known of these are the French Lick and West Baden Springs, Trinity and Indian Springs. Lost River, a main branch of the East Fork, through Orange and Martin counties, has many "lost" tributaries in Orange County. The numerous caves and the mineral springs are described in the State Geologist's Reports for the years 1896 and 1901-02.

The greater or less degree of uniformity in the volume of the river in the course of a year is one of its chief physical features and depends very much on the manner in which the water supply is obtained. The streams of this area depend for their increase wholly upon the rains, which, occurring frequently and at no fixed periods, and discharging only comparatively small amounts of water at a time, except in periods of the heavy rainfall of several days' duration, preserve a moderate degree of uniformity in the volume of the streams. This uniformity is aided by the fact that under normal conditions only about one-third of the rainfall finds its way directly over the surface to the streams, the remaining two-thirds sinking into the ground and finding its way to springs, reservoirs, or gradually oozing through at a lower level until the soil becomes drained of its surplus moisture, a process which continues for weeks and helps to keep up the volume of the stream. But, on the other hand, man has done a great deal to destroy the uniformity of the volume. By the removal of the forests, the cultivation of the soil, and the use of ditches for drainage, a greater part of the water is at once thrown into the stream and greater fluctuations occur. Owing to the streams being hemmed in by lofty, abrupt cliffs, which resist the free passage of the swollen streams, and the velocity being checked by winding courses, greater floods occur from the same amount of rainfall than formerly.

View upper half of the Pinnacle, Shoals, Ind. Distance from top to water level 196 feet.

Hanging Rock, an undercut sandstone cliff, southwest Lacy, Martin County.

Showing laminated structure and joints in the New Albany Black Shale. Scott County.

Rectangular Blocking in the Huron Limestone. Greene County.

Jug Rock, a column of sandstone capped with a harder layer of sandstone. (See description.)

House Rock, a cave formed by the tilting of large blocks of sandstone, north of Shoals, Martin County.

View in Salt Creek Valley, showing high terraces in background, southeast Stobo, Monroe County.

Recent terraces in Salt Creek Valley southeast of Stobo, Monroe County.

**Salt Creek Valley near Harrodsburg, Monroe County.**

**White River Valley, looking north from the Pinnacle, Shoals, Ind.**

Gullies in the clay and shale of the Knobstone, eastern Monroe County.

Recent gullies in clay and shale, eastern Monroe County.

Showing east side of City Waterworks Reservoir, Bloomington. The water is supplied by springs from the underground drainage of sink-hole region in Mitchell limestone.

Boating along Public Highways during Spring Flood, 1906, in River Valley near Shoals.

Undercut Sandstone Cliff with overhanging Icicles, southern Martin County.


The Glen, an undercut sandstone cliff with an intermittent cascade, Shoals, Martin County.

View looking northeast from Weedpatch Hill, showing Knobstone topography.

Many gravelly and rock bottom streams are used as public roads. This view in southern Martin County.

Silurian exposure on the Muscatatuck directly south of Vernon.

View on Clear Creek along Monon Railroad between Bloomington and Harrodsburg.

## Steps in the Development of a Smokeless City.

W. F. M. Goss.

1. *The Presence of Smoke* in those cities of our country which are within easy reach of its soft coal mines is becoming more serious every year. People are beginning to understand that this smoke which, in earlier days, was welcomed as evidence of a city's growth, and of its industrial prosperity, is, in fact, a source of heavy expense to all of its citizens. The annual smoke bill of such a city as Indianapolis is, in fact, enormous! This arises, not from the loss of fuel or heat in the form of smoke, for that is so small as to be almost negligible, but in the damage which is wrought by its presence, upon the architectural embellishment of the city, upon the fixtures and furnishings of its homes, and upon the apparel of its citizens. Loss also occurs through the extensive use of artificial light which the presence of smoke enforces, and because of its effect upon the welfare of those from whom it shuts out the sunlight and takes away the purity of the atmosphere.

Thus far urban communities have sought to protect themselves through prohibitive legislation, with the result that while flagrant abuses have sometimes been abated, the atmosphere of the city as a whole has not materially improved. It is doubtful if such legislation, unsupported by corrective measures which are broadly co-operative, can ever be made an effective instrument in the abolition of smoke. The problem is one of many complications and its solution can only be reached through action based upon a full understanding of difficulties to be overcome.

2. *The Sources of Smoke* in cities may be separated into five different groups, each of which will require different treatment. They are as follows:

1. Large furnace fires such as are employed in metallurgical processes.
2. Large boiler plants, by which is meant all plants in excess of 500 horse-power.
3. Small boiler plants and small industrial fires.
4. Domestic fires.
5. Locomotive fires.

Accepting this classification as a convenient one for the purpose in hand, we may inquire as to the process by which the smoke now being delivered by each of the several groups is to be eliminated.

3. *Large Fires Such as Are Employed in Metallurgical Processes.* Except in a few cities, of which Pittsburg is the best type, the proportion of the total smoke delivered from such fires is small. In the city of Indianapolis, for example, it is exceedingly small. Moreover, the managements of industries using such fires are, in many cases, finding increased efficiency in operation by the installation of gas producers which receive the coal and deliver highly heated gas for use in the furnaces. The gas producer makes smokeless the process of converting coal into heat. As its use under a wide range of conditions will result in economy in operation, no injury would be done by the prohibition of smoke from all fires which might properly be served by producer gas, provided a reasonable period is allowed between the passage of the prohibitive ordinance and its going into effect. Fires of this group which can not be thus treated in such cities as Indianapolis will be so few that their effect will be negligible.

4. *Large Boiler Plants.* The suppression of smoke from fires of this class by the adoption of a suitable automatic stoker, will effect an economy in operation, hence owners will not seriously object if they are required, after suitable notice, to so equip their plants. An ordinance requiring all boiler plants of more than 500 horse-power to be thus equipped within three years of the date of its passage would not be unreasonable.

5. *Small Boiler Plants and Small Industrial Fires.* Referring first to boiler plants, it should be noted that the fires of this group are ordinarily prolific sources of smoke. Boilers of 100 horse-power or less are all over the modern city. Generally speaking, no economy can result from the application of automatic stokers to these small boiler plants and hence owners can not be influenced to add to their fixed charges in the expectation of securing a money return. The requirement that such furnaces employ anthracite coal, coke, or other smokeless fuel, would in all cases work serious hardship and in many cases it would be prohibitive. The wisest and most effective course to follow with reference to such fires is to provide a satisfactory substitute, then abolish them. So far as such plants are now employed in the production of power, they can be rendered unnecessary through the cheaper and more effective distribution of electrical power. So far as steam from such boilers may at present be used for heating they can be rendered of no effect through the supply of heat from a

central station. There are, however, in every large city many minor industrial establishments, such as dye works, bleacheries and laundries, requiring steam at high pressure, and for these a general system of supply from a central plant must be provided. That this may be the more readily accomplished, such industries should be encouraged to group themselves within a prescribed area to better accommodate themselves to some reasonable plan of steam distribution. To properly supplant the fires of numerous small boilers now in service, it will be required, therefore, that stations be established throughout the business portion of the city, capable of delivering electric current for power and lights, steam or hot water for heating, and a limited amount of high pressure steam for industrial uses; these central plants to be of sufficient size to justify the use of stokers which will make them smokeless. When by municipal co-operation these shall have been provided, under conditions which will safeguard the interests of all consumers with reference to costs, then it will be in order to prohibit, after a series of years, the use of soft coal under all boilers of the city, except in connection with automatic stokers.

Small industrial fires other than those under boilers should be sustained by gas drawn from sources hereinafter referred to.

6. *Domestic Fires.* While individual domestic fires are not the source of heavy volumes of smoke, their number in any city is large, and their effect in the aggregate as a source of smoke is as pronounced as that of any other single group of fires. So long as soft coal can be had more cheaply than anthracite coal, just so long will there be a desire on the part of the consumers to employ it in domestic service. Domestic fires being small, it is impracticable to apply to them effectively the principles of smokeless firing. A necessary step, therefore, in the development of a smokeless city is a complete prohibition of the use of soft coal for domestic purposes. As a preliminary step, two things are essential. First, a supply of low-priced gas for use in cooking; and second, the distribution from a central station of large capacity of steam or hot water for domestic heating.

There are no real problems in the supply of gas for cooking except such as may grow out of existing franchises. At prices now prevailing, this form of fuel is much used in cooking and generally is less expensive for that purpose than solid fuels. Add to this the fact that the cost of gas to the producer is reduced as the quantity sold is increased, and an abundant supply at a cost sufficiently low to permit all people in a city to

use it for cooking, becomes not only possible, but attractive as a means of economy.

The establishment of centralized heating plants of sufficient size to justify the maintenance of smokeless fires therein, and in such number as to serve an entire city, constitutes a problem presenting no serious engineering difficulties. Such a system would need to be developed under sufficient municipal control to insure satisfactory service to all portions of the city and to guarantee to the consumers of heat a cost not greater than is required to insure a fair return upon the investment made. Enough has already been accomplished in heating from central stations to insure the practicability of such a scheme. While the loss of heat in transmission is necessarily large, this loss is more than neutralized by the use of low grade coal in the central station, in the place of high grade fuel now employed in domestic heating, so that, basing an estimate on the heat delivered, the cost should not be greater than under present conditions of domestic heating. Attention should be called to the fact, however, that such a system would be easily practicable even at some advance in cost, for freedom from smoke and the convenience of a supply of heat from outside sources are matters for which people will be willing to pay.

7. *Locomotive Fires.* These, in railroad centers such as Indianapolis, are prolific sources of smoke. Moreover, if soft coal is permitted to be used in fire-boxes the delivery of smoke from locomotive stacks can not be prevented. As a consequence, prohibitive legislation in various American cities has thus far had but little effect in reducing the amount of smoke delivered from locomotive fires. It is not the fault of the railway management; it is due to the difficulties which are inherent in the case. There are, in fact, but two ways out of the difficulty, and the acceptance of either solution will involve railway companies in heavy expenditures and will entitle them to concessions or direct aid from municipalities. The first and simplest is to be found in the requirement of all steam locomotives operating within the smoke limits of a city, to be supplied with smokeless fuel, that is, with anthracite coal or with coke; the second solution is to be found in the prohibition of the use of steam locomotives and in the substitution of electric locomotives within the smoke limits of the city.

The development of either of these plans will involve the establishment of locomotive terminals upon every road outside of the smoke limits of the city. By the use of such terminals the road locomotive of an approaching train can be stopped before reaching the city, its place being taken

either by a steam locomotive using coke or anthracite coal for its fuel, or by an electric locomotive which will serve to carry the train on to the city, and afterward out of the station and across the city to another terminal where it will stop, its place at the head of the train being taken by another road locomotive having its usual supply of soft coal. Such a plan has been put into effect in New York City, and has been settled upon for Washington, D. C., where the commissioners of the District of Columbia, on November 17th, took final action on an order to prohibit the use of any except electric locomotives in drawing trains into the new Union Station. Excepting in very large cities, however, the cost of electric transmission will be prohibitive. It will be far cheaper for railway companies, and quite as satisfactory to the urban communities, to admit steam locomotives, provided they are supplied with a fuel which prevents smoke.

It is evident that procedure under this outline with reference to locomotive fires must necessarily involve plans extending through a series of years. An equitable scheme of co-operation between the railroads and the city must be devised, plans must be made and adopted, and time must be given for financing and executing them.

In the working out of the general plan described by this brief outline for the elimination of smoke, many difficulties are to be met and antagonistic interests to be harmonized, but there is nothing which, from an engineering point of view, is impracticable, or which can not, as a business matter, be reduced to a satisfactory procedure. A city, to be made smokeless by the measures suggested, would first seek to fix limits defining the area to be controlled. Within this area would be developed a series of power and heating plants which would be spaced upon a system of squares in the business portions, at intervals of a mile or a mile and a half, and in the residence portion at intervals of two miles. From these several stations would go out currents of electricity for all power and light needed by the city. From certain of them steam at high pressure for industrial purposes would be distributed over the limited areas and from all of them would go out steam or hot water for heating. By a suitable grouping of equipment within these stations, those in the residence portions would be made to serve as heating plants alone and hence would be out of service during a considerable portion of the year. Because of their size and the perfection of equipment, all would be operated by smokeless fires. All small fires, which at the present time serve for heating and power in individual buildings, would cease to exist, and large fires under boilers of great industries

and in furnaces of metallurgical establishments, would be made smokeless by means which would enhance their economy in operation. Railroad trains passing through the controlled area would be drawn by smokeless locomotives, and above and around the city a clear atmosphere would contribute to the cleanliness of all things and to the comfort and peace of mind of all its people.

# Experimental Studies in Reinforced Concrete.

W. K. Hatt.

It was the comfortable assurance of that urbane Roman poet, Horace, that he had built himself a monument more lasting than brass in the intellectual life of mankind. At the time that he was writing these lines the Roman engineers were constructing those concrete aqueducts and domes that have served mankind on the physical side during the time that Horace had been a source of perpetual delight to the students of classical writings. Which product will endure the longer is an open question. One thing is certain, while many persons of exquisite taste may prefer Horace to our modern writers, all well-informed persons conclude that the engineer of today has surpassed the Roman engineer in the quality and use of concrete.

The number of recent failures of reinforced concrete buildings, attended with the loss of life of workmen, does not constitute an argument against the advance of the practice of this new art, but calls attention to the need of correct theory in design and expert supervision in construction. Steel for buildings is made under highly technical methods, and a searching inspection by trained men, whereas concrete for buildings may be formed by ignorant and unskilled workmen, and may be supervised by foremen who are mostly inexperienced in the art of proportioning and mixing the ingredients. Defective material, either of cement, sand or stone, dishonest skimping of cement and poor inspection, incorrect proportioning, and a too early removal of the wooden forms from the floors molded in cold weather, or heavily laden with stored cement and other materials, are sufficient causes to explain these failures. An increasing number of these may be expected as time goes on and untrained men who have learned their business in other lines of construction, take up the work of building reinforced concrete structures. The resulting loss of life will no doubt call attention to the necessity of regulating by proper building laws this new construction, which has spread so rapidly over the country from sea to sea. In 1902, when the first published results of experimentations appeared in this country from the Laboratory for Testing Materials of Purdue University,

one had to go far to observe instances of reinforced concrete. Last summer in Seattle the writer saw no other type of building in process of construction. At Atlantic City in 1902, when the experiments referred to were placed before the American Society for Testing Materials, there was no instance of the use of reinforced concrete in sight. Last summer, at the meeting of the Society, one viewed the stately and beautiful Marlborough-Blenheim hotel entirely constructed of reinforced concrete; the replacement of the steel pier by reinforced concrete piles and girders; and the construction of a new recreation pier of this type of construction. The growth has been truly marvelous. Not only has the extent of its use in bridges and buildings increased, but the variety of its application is extraordinary. In a list of constructions in which it is successfully and economically used may be included: Retaining walls, dams, tanks, conduits, chimneys, arches, culverts, foundations, floors for buildings, railroad girders, highway bridges, pipes, railway ties, piles, stairs and roofs.

At the present time the underlying mechanical principles and the constants of design are fairly well determined, and we wait upon the architects to express the truth of these principles in a beautiful structure. While this type of construction associates itself with the broad and simple wall spaces and low buildings of the Spanish Mission style, with surface ornaments of tiling and Mosaic, it also lends itself to important modern civic buildings. The stateliness of beauty of the Marlborough-Blenheim Hotel at Atlantic City has been mentioned. The Ingalls Building, Cincinnati, and the new Terminal Station at Atlanta, Ga., are other examples.

Without stopping to discuss the properties of waterproofness, fireproofness, durability, etc., or the multitude of topics of interest and importance that crowd one's mind in connection with reinforced concrete, attention will be simply called to the mechanical principles underlying the construction.

Concrete, like stone, is weak in tension, but strong in compression at a ratio of 1 to 10. Consequently when under flexure, as in a beam, the concrete is not used economically; for it breaks on the lower side in tension before the compressional strength is utilized. A beam may be, however, strengthened, or *reinforced*, by the insertion of a steel rod in the lower side of the beam. These rods are usually bent up near the ends of the beam so as to also reinforce the beam against the diagonal tensional stresses that occur at the ends, due to the combination of shear and direct stress.

Before the rod can come into operation during a flexure of the beam, there must be the necessary adhesion between the concrete and the rod to transfer the stress to the rod, and bring the latter into action. This adhesion varies from 300 pounds to 500 pounds per square inch of the surface of the rod, and under favorable conditions is sufficient to develop the strength of the steel in the concrete. The adhesion seems to be more of a mechanical action than chemical, and is due to the entrance of the fine cement into the microscopic pits on the surface of the smooth rods. Many designers use artificially deformed bars, such as corrugated bars and twisted steel bars, to increase this adhesion.

In this way a beam is reinforced so that both the concrete in compression and the steel in tension may be worked to their full value. Any one who has seen a plain concrete beam broken in a testing machine, and then has witnessed a test of a reinforced concrete beam, will be first of all struck by the apparently greatly increased flexibility of the reinforced concrete beam, which deflects ten times as much as the plain beam before showing any visible cracks, and when the load is removed the elasticity of the steel draws the beam back nearly to its original shape. It is probable, however, that this process of bending the reinforced concrete beam early develops very minute flaws in the concrete which are invisible to the naked eye, so that it is not safe to count upon a tensile strength of the concrete in computing the total resisting strength of the beam. Designers compute the resisting moment of the beam as based upon the compressional stresses in the concrete and the tensional stress in the steel alone.

The original tests at Purdue University were arranged to determine:

1. The increased strength added by a given amount of steel inserted in a plain concrete beam.

2. The law connecting the strength of the beam with the amount of steel.

3. The law connecting the strength of the beam with the position of the rods in the beam.

4. The value of gravel in reinforced concrete.

To determine these relations a series of concrete beams was made of first-class materials with rich mortar. In other words, the beams were carefully made with a combination of one part cement to two parts of sand and four parts of broken stone. The concrete was probably superior to that made in the ordinary process of construction. This was proper because the theoretical laws were being verified, and for that purpose it was

necessary to have uniform materials of good quality. The elements of the strength of the materials entering into the beams were determined first of all; namely, the compressive and tensional strength of the concrete, together with the modulus of elasticity of the concrete, both in tension and compression; the adhesion between the cement and the steel; the elastic limit of the steel; a mechanical analysis made of the materials. Since the beams were long in span compared to their height, and, therefore, the shearing stresses were not important, rods of smooth steel were used. Having determined all the elements entering into the strength of the beam, and then the tested strength of the beam itself, it next became necessary to formulate a mechanical analysis of the combination of steel and concrete in flexure, and, with the experience of the tests of the beams in hand, to derive equations for design and calculation. The truth of these equations and the validity of the process of the analysis could then be checked by reference to the tested strength of the beams. These equations were derived and have been used very largely by engineers throughout the country in designing reinforced concrete structures.

Engineers as a rule have found it necessary to review their knowledge of mechanics in dealing with reinforced concrete, not that there is any new principle involved, but the number of factors in the equations of flexure is greater, and an account must be taken of the relative moduli of elasticity of the two materials, steel and concrete. Furthermore, the lack of perfect elasticity of the concrete leads to an assumption of some other than a rectilinear relation between stress and strain.

Again the neutral axis of the cross section must be determined. Its location is not simply fixed by the center of gravity of the cross section, but is controlled by the amount of steel present, the relative moduli of elasticity of the steel and concrete, and by the position of the steel. The writer's equations have followed the usual assumptions of flexure, with the following special assumptions:

1. That the modulus of elasticity of concrete in tension and compression is the same.

2. That there is a parabolic relation between stress and strain in the concrete.

3. That in the earlier stages of the loading of the beam the concrete carries stress in tension, but later, at higher loads, this tensile strength may be disregarded.

The equations are somewhat cumbersome, but have been reduced to

diagrammatic form in the Transactions of The American Railway Engineering and Maintenance of Way Association, Vol. V, 1894, pages 626 and 627. Empirical equations of simple form are presented in The Engineering Review of Purdue University, Vol. I, 1905.

In calculating the strength of the reinforced concrete beam sufficiently approximate results can be obtained by omitting consideration of the tensile stresses in the concrete, and supposing a rectilinear relation between stress and strain. The moment of flexure is then most simply expressed as the total force in the steel multiplied by the distance to the centroid of the compressive stresses. This latter distance is expressed with sufficient accuracy as a fraction of the depth of the beam, this fraction having been determined by experimental measurement on the tested beams.

Care in all cases must be taken to compute the maximum compressive stress arising in the concrete under the conditions of the problem, and also the amount of diagonal tension at the ends of the beams must be computed and provided for by stirrups, or by bending up some of the rods at the ends.

To conclude this brief consideration of reinforced concrete, a conservative estimate would include the following principles:

1. Concrete is durable and fireproof when made of the proper aggregate.

2. The strength of combination of steel and concrete may be calculated with a sufficiently close degree of accuracy.

3. Shapely and beautiful structures may be built of this material. It is particularly adapted for mill buildings because of the absence of vibrations which are induced in the ordinary type of mill buildings by the rapidly revolving machinery.

4. The cost of a properly designed reinforced concrete building, where wooden forms are used to advantage, need not exceed more than 5 or 10 per cent. of the cost of mill buildings of the ordinary type with brick walls and wooden beams of the so-called slow-burning construction, provided that the concrete may be laid as at present by unskilled labor.

# The Newer Hygiene.

Wilfred H. Manwaring.

Instruction in the nature of infectious diseases, especially in the means of transmitting these diseases from one person to another, is required by law in all our public schools. This law is of great value; for it is only through the intelligent co-operation of a well-informed public that hygienic and sanitary measures designed to control and stamp out infectious diseases can be successful. A wide diffusion of this knowledge will go far to make tuberculosis a thing of the past, and diphtheria and smallpox unknown.

In obedience to the legal requirement, there are taught, in our public schools, certain elementary facts regarding the nature of pathogenic bacteria, and certain facts regarding the ways in which these bacteria are transmitted from one person to another. These facts in themselves are of inestimable value, but they are insufficient.

The presence of bacteria within or upon the human body, the transmission of disease-germs from the sick to the well, is but one of the factors tending to cause disease. To acquire a disease it is usually necessary, not only to acquire the germs of that disease, but there must be a lowering of bodily resistance as well.

Every fourth person in this room is carrying daily in his throat or mouth virulent pneumococci. Yet he does not acquire pneumonia. And why? Because there is an efficient defense against this disease in the healthy human body. Some day this defense will be lowered and pneumonia develop. Most soldiers in the Philippines carry in their intestinal canals virulent germs of dysentery; and with no ill effects, till intoxication or dietary excesses lower the intestinal resistance. We daily inhale germs of tuberculosis. Some day, when our resistance is low, we will acquire the disease.

A knowledge of the body's fighting power against bacteria, a knowledge of the ways in which that power can be increased or decreased by hereditary influences and by modes of life, is therefore of hygienic importance. It should form part of the curriculum of every public school.

The body fights disease in many ways. It will be sufficient for hygienic purposes to teach but three of these ways: (i) the method of antitoxines; (ii) the method of antiseptics and (iii) the method of phagocytosis.

There ar many diseases in which the symptoms are caused, not by the bacteria themselves, but by the poisons the bacteria manufacture. Thus, in tetanus, or lockjaw, the bacteria grow, perhaps unnoticed, at the bottom of the Fourth-of-July wound on the hand or foot; but the chemical poisons they manufacture, carried by the blood to the brain and spinal cord, cause the spasms and convulsions that characterize the disease. In diphtheria the bacteria rarely enter the body, but grow in grayish-white masses on the moist surfaces of the mouth and throat. The chemical poisons they manufacture, absorbed by the tissues, cause the paralysis and heart failure that characterize the disease.

The body has the power of forming substances that neutralize these poisons. To these neutralizing substances the name antitoxine has been given.

This fact is of hygienic importance for two reasons: First, because it is sometimes possible to assist the body in its efforts to form antitoxines, by introducing into it antitoxines artificially prepared; and, second, because the body's power to form these substances is modified by mode of life.

A horse that has been repeatedly injected with the poisons manufactured by the germs of diphtheria, grown on artificial culture media, develops enormous amounts of diphtheria antitoxine. A few drops of the serum of this horse renders harmless large quantities of diphtheria poison. Through the use of diphtheria antitoxine in practical medicine, the mortality from diphtheria has been reduced from the 24 per cent. to 40 per cent. it was, twenty years ago, to the less than 1 per cent. it now is, in well-treated cases. Overwork, insufficient clothing, improper food, alcoholic excesses, lack of sleep, and other factors, so lower the antitoxine-forming power of the body as to greatly increase the dangers from infection.

The second way of hygienic significance in which the body fights disease, is by the formation of chemical substances that, although they have no influence on the chemical poisons manufactured by bacteria, have an even more important property, that of killing the bacteria themselves.

The presence of antiseptic, or bacteria-killing substances in the blood and tissue juices is easily shown. One has but to mix bacteria with serum

and test from time to time, by simply cultural methods,* whether or not the bacteria are alive. Thus, in one experiment, there were mixed with human serum typhoid fever germs in such numbers, that every drop of the serum contained 50,000 bacteria. Two minutes later but 20,000 of these were alive; at the end of ten minutes, but 800; and in twenty-five minutes, they were all dead.

Not only can serum kill bacteria, but most of the secretions of the healthy human body are bacteria-killing as well. Gastric juice, vaginal secretion and nasal secretion, kill bacteria in enormous numbers. The hygienic significance of this is evident from the fact that these bacteria-killing substances, also, are modified by modes of life. Dietary excesses may so lower the bacteria-killing properties of gastric juice, and unsanitary conditions so lessen that of the tissue juices that susceptibility to infectious diseases is greatly increased.

The third way of hygienic importance in which the body fights disease, is by phagocytosis. In the body there are millions of white blood corpuscles, each having the power of independent motion and as one of its functions the faculty of eating and destroying disease germs.

It is found that the bacteria-eating power of white corpuscles is largely dependent upon certain chemical substances† present in the blood and tissue juices. Without these chemical substances the eating of certain pathogenic bacteria does not take place. With them, it is very active. It is further found that these chemical substances are influenced by modes of life. That they may be increased or decreased under different hygienic conditions. Phagocytosis, therefore, has also a place in popular hygienic knowledge.

One of the unfortunate results of the spread of knowledge of pathogenic micro-organisms is the formation of an unreasoning popular fear of disease germs. It is thought that a wide understanding of facts regarding bodily resistance will tend to replace this unfortunate germ-fear by a rational faith in the body's marvelous powers. That it may turn the tide of hygienic endeavor, from an exclusive fight against bacteria to a combined fight *against* bacteria and *for* bodily resistance.

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* See Popular Science Monthly, Vol. 66, pp. 474-177.
† Opsonins.

# Concerning Differential Invariants.

David A. Rothrock.

During the last forty years wonderful progress has been made in many fields of higher mathematics. One distinct line of investigation has had to do with a *microscopic* examination of the fundamental axioms of the elementary mathematics, of conditions of convergence, of the sufficient conditions in the calculus of variations, and so on. Another essential advance has been made by unifying many separate and apparently distinct fields of mathematics under one common law. Among many advances in this latter line of work, none are more important than the work of Sophus Lie, a Norwegian, who lived from 1842 to 1899.

Lie received his doctorate from the University of Christiania in 1865, caring no more for mathematical work than for literary or philological work. In fact, he had thought of becoming an engineer; but receiving an appointment to a docentship in the university, he turned his attention to the study of advanced mathematics. The real mathematical genius of Lie was aroused by a course of lectures on substitutions by Professor Sylow. Lie's creative period seems to have extended from 1868 to about 1874, during which time he came into possession of the essential features of his epoch-making Theory of Continuous Groups. The remainder of his life was devoted to the elaboration of his early conceptions, and to the applications of his theories. A general development of the higher number systems, a classification of ordinary and partial differential equations, with methods of their solutions, invariants and covariants, many problems of physics and astronomy, are all treated from the standpoint of the continuous group. Below is sketched a brief outline of the continuous group theory of Lie, as applied to differential invariants, and the calculation of an important differential invariant is indicated.

1. *Point Transformation.* Let x, y be the Cartesian coördinates of any point in the plane, and let $x_1$, $y_1$ be any point other than x, y. Then

$$x_1 = \Phi(x, y), \; y_1 = \Psi(x, y)$$

is said to be a point transformation, carrying point x, y into point $x_1$, $y_1$. Here it is assumed that inversely

$$x = \Phi_1 (x_1, y_1),\ y = \Psi_1 (x_1, y_1)$$

carries the point from $x_1$, $y_1$ back to x, y. A point transformation may be looked upon either as a transference of axes from one system to another, not necessarily the same kind of system, or it may be considered as an actual transference of one point into another position in the plane, the axes of reference remaining unchanged.

2. *Group of Transformations.* A point transformation containing one or more parameters

$$x_1 = \Phi (x, y, a, b, c, \ldots k),$$
$$y_1 = \Psi (x, y, a, b, c, \ldots k),$$

such that for $a_0$, $b_0$, $c_0$, .... $k_0$, the point x, y transforms into itself, is said to constitute a group of transformations when a succession of two such operations may be replaced by one of the same species. That is, if

$$x_2 = \Phi (x_1, y_1, a_1, b_1, c_1 \ldots) = \Phi \left\{ \Phi (x, y, a, \ldots k), \Psi (x, y, a, \ldots k), a_1 \ldots k_1 \right\}$$
$$= \Phi (x, y, a_2, b_2, c_2, \ldots k_2),$$
$$y_2 = \Psi (x, y, a_2, b_2, c_2, \ldots k_2),$$

where $a_2 = f_1 (a, b, \ldots k, a_1, b_1, c, \ldots k_1)$, $b_2 = f_2 (a, b, \ldots k_1)$ ...., then

$$x_1 = \Phi (x, y, a, b, \ldots k),\ y_1 = \Psi (x, y, a, b, \ldots k)$$

are the transformations of an $r$-parameter group, the parameters a, b, c, ... k being $r$ in number and independent. A similar definition may be given to a group in one, three, four, or $n$ variables*.

3. *The Infinitesimal Transformations.* An infinitesimal transformation is defined analytically by

$$\delta x = \xi (x, y)\, \delta t,\ \delta y = \eta (x, y)\, \delta t.$$

Such a transformation attaches to any point x, y an infinitesimal motion whose projections on the x —, and y — axes are respectively, $\xi \delta t$ and $\eta \delta t$, and whose distance is $\sqrt{\xi^2 + \eta^2}\, \delta t$. Lie shows such infinitesimal transformations to belong to a single-parameter group.

$$x_1 = \Phi (x, y, a),\ y_1 = \Psi (x, y, a).$$

This may be easily seen by letting $a_0$ be the value of $a$ which leaves x, y fixed; then

$$x_1 = \Phi (x, y, a_0 + \delta a),\ y_1 = \Psi (x, y, a_0 + \delta a)$$

*See Lie—Scheffers, Differential-gleichungen, pp. 24-25.

give to the point x, y an infinitesimal motion. Expanding in powers of $\delta a$, we have*

$$x_1 = \Phi(x, y, a_0) + \left\{\frac{d\,\Phi(x, y, a_0)}{d\,a_0}\right\}\delta a + \ldots,$$

$$y_1 = \Psi(x, y, a_0) + \left\{\frac{d\,\Psi(x, y, a_0)}{d\,a_0}\right\}\delta a + \ldots.$$

But $\Phi(x, y, a_0) = x$, $\Psi(x, y, a_0) = y$, hence

$$x_1 = x + \left\{\frac{d\,\Phi}{d\,a_0}\right\}\delta a + \ldots,$$

$$y_1 = y + \left\{\frac{d\,\Psi}{d\,a_0}\right\}\delta a + \ldots,$$

$$\delta x = \left\{\frac{d\,\phi}{d\,a_0}\right\}\delta a + \ldots \quad = \xi(x, y)\,\delta t + \ldots,$$

$$\delta y = \left\{\frac{d\,\psi}{d\,a_0}\right\}\delta a + \ldots \quad = \eta(x, y)\,\delta t + \ldots.$$

Omitting infinitesimals of higher order we have the relations

$$\delta x = \xi(x, y)\,\delta t, \quad \delta y = \eta(x, y)\,\delta t$$

as the infinitesimal transformations of a one-parameter group.

In the notation of Lie the symbol

$$U f \equiv \xi(x, y)\left\{\frac{d f}{d x}\right\} + \eta(x, y)\left\{\frac{d f}{d y}\right\},$$

denoting the variation which a function $f(x, y)$ undergoes when x, y receive the increments $\delta x$, $\delta y$, is employed as the symbol of an infinitesimal transformation. Writing p, q instead of the partial derivative of $f(x, y)$ with respect to x and y, respectively, we have

$$U f \equiv \xi(x, y)\,p + \eta(x, y)\,q.$$

The infinitesinal transformations of an $r$-parameter group would be given by the symbol

$$U_k f \equiv \xi_k(x, y)\,p + \eta_k(x, y)\,q, \quad k = 1, 2, 3, \ldots r.$$

4. *The Group Criterion.* One of Lie's fundamental theorems furnishes a test whether or not any given set of infinitesimal transformations, $U_k f$, $k = 1, 2, \ldots r$, actually forms a group. This test is the application of Jacobi's *bracket expression*

$$U_i(U_j f) - U_j(U_i f), \quad (i, j = 1, 2, \ldots r, \text{ in all combinations}).$$

*In this article the symbol $\left\{\frac{d\ f}{d\ x}\right\}$ will be used to denote the partial derivative of f with regard to x, instead of the round d usually employed.

If the Jacobi bracket-expression, constructed for all combinations of i, j, is equivalent to a linear function of the symbols $U_k f$ with constant coefficients, then are the symbols

$$U_k f \equiv \xi_k(x, y)\, p + \eta_k(x, y)\, q, \quad k = 1, 2, \ldots r,$$

the infinitesimal transformations of an $r$-parameter group.*

5. *The Extended Group.* An infinitesimal transformation

$$U f = \xi(x, y) \left\{\frac{d f}{d x}\right\} + \eta(x, y) \left\{\frac{d f}{d y}\right\}$$

may be *extended* in two ways. In the first place, the variation of the coördinates of $n$ points is simply the sum of the variations of the coördinates of the separate points; hence, $U f$ extended in this manner becomes

$$\text{(A)}. \quad U f_n = \sum_{k=1}^{k=n} \left\{ \xi_k(x_k, y_k) \left\{\frac{d f}{d x_k}\right\} + \eta(x_k, y_k) \left\{\frac{d f}{d y_k}\right\} \right\}.$$

The symbol $U f$ may also be extended so as to include the variation of $y' = \frac{d y}{d x}$, $y'' = \frac{d^2 y}{d x^2}$, ...., $y^{(n)} = \frac{d^n y}{d x^n}$. We have

$$\delta x = \xi(x, y)\, \delta t, \quad \delta y = \eta(x, y)\, \delta t.$$

$$\delta y' = \delta \frac{dy}{dx} = \frac{dx\, \delta\, dy - dy\, \delta\, dx}{dx^2} = \frac{d\, \delta\, y - y' d\delta\, x}{dx}$$

$$= \left\{\frac{d\eta}{dx} - y' \frac{d\xi}{dx}\right\} \delta t = \left\{\eta_x + y' (\eta_y - \xi_x) - y'^2 \xi_y\right\} \delta t$$

$$= \eta'(x, y, y')\, \delta t.$$

In a similar manner,

$$\delta y'' = \left\{\frac{d\eta'}{dx} - y'' \frac{d\xi}{dx}\right\} \delta t = \eta''(x, y, y', y'')\, \delta t,$$

and so on for higher variations.

The infinitesimal transformation $U f$ extended to include these higher variations becomes

$$\text{(B)}. \quad U f_n = \xi \left\{\frac{df}{dx}\right\} + \eta \left\{\frac{df}{dy}\right\} + \eta' \left\{\frac{df}{dy'}\right\} + \eta'' \left\{\frac{df}{dy''}\right\} + \ldots + \eta^{(n)} \left\{\frac{df}{dy_n}\right\}.$$

Each of the members of an $r$-parameter group $U_k f$, $k = 1, 2, \ldots r$, may be extended, giving the infinitesimal transformations of the coördinates of $n$ points as indicated by equation (A); or each may be extended as in (B) to include the variations of $x$, $y$, $y'$, $y''$, $y'''$, ... $y^{(n)}$. A group of transformations extended in style of (A) or (B) is called an extended group.

*Lie—Scheffers, Continuierliche Gruppen, p. 390.

6. *Invariant Functions.* The variation of any function $\Phi$ (x, y) when operated upon by an infinitesimal transformation.

$$U f \equiv \xi p + \eta q$$

is given by

$$U \Phi \equiv \xi \left\{ \frac{d \Phi}{dx} \right\} + \eta \left\{ \frac{d \Phi}{dy} \right\}.$$

If $\Phi$ (x, y) is to remain unchanged, then $U \Phi \equiv o$, and $\Phi$ (x, y) is a solution of the homogeneous linear partial differential equation

$$U f \equiv \xi p + \eta q = o,$$

that is, $\Phi$ (x, y) is an integral of Lagrange's equation

$$\frac{dx}{\xi} = \frac{dy}{\eta}.$$

$\Phi$ (x, y) so determined is called an invariant for the transformation

$$U f \equiv \xi p + \eta q.$$

A group of two or more independent transformations will not in general have an invariant function. But when extended to include the coördinates of *n* points, as in (A) above, an *r*-parameter group

$$U_k f_{(n)} \equiv \sum_{i=1}^{n} \left\{ \xi_k (x_i, y_i) \left[ \frac{df}{dx_i} \right] + \eta_k (x_i, y_i) \left[ \frac{df}{dy_i} \right] \right\}, \ k = 1, 2, \ldots r,$$

gives rise to 2 n — r independent functions

$$\phi_1 (x_1, y_1, \ldots x_n, y_n), \phi_2, \phi_3, \ldots \phi_{2n-r}'$$

which are *point-invariants* of the group $U_k f$, and which are derived by integrating the *r* partial differential equations $U_1 f_n = o$, $U_2 f_n = o$, ... $U_r f_n = o$.

After the manner here indicated the writer has calculated all the point-invariants for the twenty-seven finite continuous groups of the plane as classified by Lie.* The results appear in the Proceedings of the Indiana Academy of Science, 1898, pp. 119-135.

7. *Differential Invariants.* An infinitesimal transformation extended to include the increment of y′ leaves invariant two functions $\phi_1$ (x, y, y′), $\phi_2$ (x, y, y′), the solutions of

$$U' f \equiv \xi p + \eta q + \eta' \left\{ \frac{df}{dy'} \right\} = o.$$

The functions $\phi_1$, $\phi_2$ are called differential invariants of the infinitesimal transformation $U' f$. Lie shows that when two independent differential

*See Lie-Scheffers, Contin. Gruppen, pp. 360-362.

invariants of a given transformation are known, then all others may be found by differentiation.*

$$\phi_3 = \frac{d\phi_2}{d\phi_1}, \ \phi_4 = \frac{d\phi_3}{d\phi_1}, \ \dots .$$

An $r$-parameter group $U_k f$ extended to include the increments of $y', y'', \dots y^{(r)}$, when equated to zero, gives $r$ partial differential equations in $r + 2$ variables. These $r$ equations have two independent solutions, $\phi_1(x, y, y', \dots y^{(r)})$, $\phi_2(x, y, y', \dots y^{(r)})$, which are differential invariants of the $r$-parameter group. After the plan here indicated Lie has calculated the differential invariants for the twenty-seven groups of the plane.

The calculation of differential invariants may be made by an entirely different method than that used by Lie, and indeed without any knowledge of the group extended as indicated above. A knowledge of the form of a point invariant for the group is necessary.

Let a point invariant $\phi(x_1, y_1, x_2, y_2, \dots)$ be given, and suppose the points $x_1, y_1; x_2, y_2; \dots; x_n, y_n$, to be located upon a plane curve

$$x = f_1(t), \ y = f_2(t).$$

Then we would have

$$x_1 = f_1(t_1), \ y_1 = f_2(t_1), \ \dots \ x_n = f_1(t_n), \ y_n = f_2(t_n),$$

Allowing $x_2, y_2; x_3, y_3; \dots; x_n, y_n$ to coalesce toward $x_1 y_1$, we may then expand $x_2, y_2, \dots$ in power-series

$$(I)\ \begin{cases} x_2 = x_1 + x' dt_2 + x'' \dfrac{dt_2^2}{2} + \dots, & y_2 = y_1 + (y') dt_2 + (y'') \dfrac{dt_2^2}{2} + \dots, \\ x_3 = x_1 + x' dt_3 + x'' \dfrac{dt_3^2}{2} + \dots, & y_3 = y_1 + (y') dt_3 + (y'') \dfrac{dt_3^2}{2} + \dots, \end{cases}$$

and so on for $x_4, y_4, \dots x_n, y_n$, where

$$(1) \qquad x' = \frac{dx_1}{dt_1}, \quad x'' = \frac{d^2 x_1}{dt_1^2}, \quad x''' = \frac{d^3 x_1}{dt_1^3}, \ \dots ,$$

$$(2) \qquad (y') = \frac{dy_1}{dt_1}, \quad (y'') = \frac{d^2 y_1}{dt_1^2}, \quad (y''') = \frac{d^3 y_1}{dt_1^3}, \ \dots .$$

The notation of (1), (2) should be changed from parameter notation to the ordinary $y' = \frac{dy}{dx}$, $y'' = \frac{d^2y}{dx^2}$, ....

$$(3)\ \begin{cases} y' = \dfrac{dy}{dx} = \dfrac{(y')}{x'}, \text{ hence } (y') = y' x', \text{ similarly,} \\ (y'') = y'' (x')^2 + y' x''; \ (y''') = y''' (x')^3 + 3y'' x' x'' + y' x'''; \\ (y^{iv}) = y^{iv} (x')^4 + 6y''' (x')^2 x'' + 3y'' (x'')^2 + 4y'' x' x''' + y' x^{iv}; \\ (y^{v}) = y^{v} (x')^5 + 10 y^{iv} (x')^3 x'' + y''' \left(15 x' (x'')^2 + 10 (x')^2 x'''\right) + \\ \qquad y'' \left(10 x'' x''' + 5 x' x^{iv}\right) + y' x^{v}, \end{cases}$$

and so on for higher derivatives.

*Lie, Math. Annalen, Bd. XXXII.

If in any point invariant $\phi$, the values of $x_2, y_2; x_3, y_3 \ldots.$, taken from (I) be substituted, and then the result developed into in infinite power-series in the ascending powers of $dt_2, dt_3, dt_4, \ldots dt_n$, the successive coefficients of the separate powers of $dt_2, dt_3, \ldots$, and of the products $dt_2, dt_3, \ldots$ are all invariant functions of $x', x'', x''', \ldots, (y'), (y''), (y'''), \ldots.$ These separate invariant functions may then be changed by means of equations (3) above so that only $x', x'', x''', x^{v}, \ldots.$ and $y' = \frac{dy}{dx}$, $y'' = \frac{d^2y}{dx^2}, \ldots..$, occur. Then by algebraic manipulation the parameters $x', x'', x''', \ldots$ may be eliminated, leaving a differential invariant for the continuous group from which the point invariant $\phi$ had been derived.

8. *The Differential Invariants for the General Projective Group.*

The general projective group: $p, q, xq, xp - yq, yp, xp + yq, x^2p + xyq, xyp + y^2q$, when extended leaves invariant the point-function.

$$Q = \left\{ \begin{vmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_5 & y_5 & 1 \end{vmatrix} \div \begin{vmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_4 & y_4 & 1 \end{vmatrix} \right\} \div \left\{ \begin{vmatrix} x_1 & y_1 & 1 \\ x_3 & y_3 & 1 \\ x_5 & y_5 & 1 \end{vmatrix} \div \begin{vmatrix} x_1 & y_1 & 1 \\ x_3 & y_3 & 1 \\ x_4 & y_4 & 1 \end{vmatrix} \right\}.^{*}$$

Substituting in Q the series expansions of $x_2, y_2, x_3, y_3, \ldots x_5, y_5$ from equations (I), and developing the determinants, we have the ratio of infinite series which may be further developed into a single power series of the form

$$Q^1 = a_0 + a_1, \left\{\frac{I_2}{I_1}\right\} + a_2 \left\{\frac{I_3}{I_1}\right\} + a_3 \left\{\frac{I_4}{I_1}\right\} + \ldots,$$

where $a_i$ is an expression containing a function of $dt_2, dt_3, dt_4, dt_5$ to degree $i$, and where

$$(K) \quad \begin{aligned} I_1 &= x'(y'') - x''(y') = y''x'^3, \\ I_2 &= x'(y''') - x'''(y') = y'''(x')^4 + 3y''(x')^2x'', \\ I_3 &= x'(y^{iv}) - x^{iv}(y') - y^{iv}(x')^5 + 6y'''(x')^3x'' + 3y''x'(x'')^2 \\ &\quad + 4y''(x')^2x''', \\ I_4 &= x''(y''') - x'''(y'') = y'''(x')^3x'' - y''(x')^2x''' + 3y''x'(x'')^2 \end{aligned}$$

and so on until all orders of differentials $y', y'', y''', \ldots., y^{viii}$ have been included. Now the separate ratios $I_2 : I_1, I_3 : I_1, I_4 : I_1, \ldots.$, are separately invariant, and when reduced as in equations (K) contain the arbitary parameters $x', x'', x''', \quad x^{viii}$. The elimination of these parameters is

*See Pro. Ind. Acad., 1898, p. 135.

a tedious process, and will not be indicated here. When performed, however, there results the two differential invariants

$$\phi_1 = \left[ 2\,A_3\,A_5 - 35\,A_2\,A_3^2 - 7\left\{ A_4 - \frac{5}{3} A_2^2 \right\}^2 \right] \div (A_3)^{\frac{8}{3}},$$

$$\varphi_2 = \left[ A_3 \left\{ A_6 - 84\,A_3\,A_4 + \frac{245}{3} A_2^3 \right\} - 12 \left\{ A_5 - \frac{35}{2} A_2\,A_3 \right\} \left\{ A_4 - \frac{5}{3} A_2^2 \right\} + \frac{28}{3} \left\{ A_4 - \frac{5}{3} A_2^2 \right\}^2 \right] : A_3^3,$$

where

$$A_2 = 3y'^{v}\,y'' - 4\,(y''')^2,$$

$$A^3 = y^{v}\,(y'')^2 - 15y'^{v}\,y'''\,y'' + \frac{40}{3}(y''')^3,$$

$$A_4 = 3y^{v'}\,(y'')^3 - 24y^{v}\,y'''\,(y'')^2 + 60y'^{v}\,(y''')^2\,y'' - 40\,y''')^4,$$

$$A_5 = 9y^{v''}\,(y'')^4 - 105y^{v'}\,(y'')^3\,y''' + 420\,y^{v}\,(y''')^2\,(y'')^2 - 700)y'^{v}\,(y''')^3\,y'' + \frac{1120}{3}(y''')^5,$$

$$A_6 = 27y^{v'''}\,(y'')^5 - 48\,A_5\,y''' - 840\,A_4\,(y''')^2 - 2240\,A_3\,(y''')^3 - 2800\,A_2\,(y''')^4 - \frac{2240}{3}(y''')^6.$$

# Conjugate Functions and Canonical Transformations.

By David A. Rothrock.

(Abstract.)

It is known that any function, $\phi(Z)$, of a complex variable, $Z = x + iy$, may be separated into a real part $\phi_1(x, y)$ an imaginary part, $i\phi_2(x, y)$, and that $\phi_1$, $\phi_2$ each satisfy Laplace's equation $\frac{\delta^2 \phi}{\delta x_2} + \frac{\delta^2 \phi}{\delta y_2} = o$.* A very elegant geometric interpretation of these two functions $\phi_1$, $\phi_2$ may be had by equating each to a third variable $\zeta$ : $\phi_1(x, y) = \zeta$, $\phi_2(x, y) = \zeta$. Each equation then represents a surface for any point of which Laplace's equation is true. By developing $\zeta = \phi_1(x, y)$ into a power series in the vicinity of any point $x_o$, $y_o$, and using the Laplace equation, we have the theorem: the projection of the section of a tangent plane to the surface $\zeta = \phi_1(x, y)$ upon the x, y-plane is a curve having a double point at $x_o$, $y_o$ with real, orthogonal tangents, and hence the surface is hyperbolic at every point.

$\zeta = k$ gives lines of level on $\zeta = \phi_1(x, y)$, while $\zeta = k_2$ in $\zeta = \phi_2(x, y)$ gives cylinders which intersect $\zeta = \phi_1(x, y)$ in *curves of quickest descent.*

The second part of the paper deals with the linear fractional function $Z_1 = \frac{\alpha\zeta + \beta}{\gamma\zeta + \delta}$ which has the fundamental invariant points $f_1, f_2$ about which a canonical transformation may be constructed so that $Z = o$, when $Z^1 = f_1$; $Z = \infty$, $Z' = f_2$. This function is $Z = \frac{Z^1 - f_1}{Z^1 - f_2} = \frac{\alpha - \gamma f_1}{\alpha - \gamma f_2}\left(\frac{Z - f_1}{Z - f_2}\right)$. The modulus of $\frac{Z - f_1}{Z - f_2}$, and amplitude of $\frac{Z - f_1}{Z - f_2}$, set, respectively, equal to constants give an elliptic system and an hyperbolic system of circles about and through the two points $f_1, f_2$. Now the transformation

$$Z = \frac{Z^1 - f_1}{Z_2 - f_2} = \frac{\alpha - \gamma f_1}{\alpha - \gamma f_2}\left(\frac{Z - f_1}{Z - f_2}\right),$$

sets up a motion about $f_1, f_2$ which is determined by the modulus and the amplitude of $\frac{\alpha - \gamma f_1}{\alpha - \gamma f_2}$. If mod. $\mp 1$ and amp $= o$, motion

*Where $\frac{\delta^2 \Phi}{\delta x^2}$ denotes the second partial of $\Phi$ with regard to x, and so for $\frac{\delta^2 \Phi}{\delta y^2}$.

goes along the hyperbolic circles, the elliptic circles interchanging. If mod. $= 1$, amp. $\mp$ o, motion goes along elliptic circles, the hyperbolic system being invariant. If mod. $\pm 1$, amp. $\mp$ o, motion is along neither family but passes diagonally from curvilinear rectangle to curvilinear rectangle. These respective transformations may be named *hyperbolic, elliptic, loxodromic*. The circles about and through the fundamental points are potential lines and lines of flow in the well known problem of electricity of equal source and sink.

BLOOMINGTON, IND., NOV. 28, 1906

## Notes on "Salt Lime."

Frank B. Wade.

"Ye are the salt of the earth; but if the salt have lost his savour, wherewith shall it be salted? it is thenceforth good for nothing but to be cast out and trodden under foot of men."—Matthew, v, 13.

This passage from "the Sermon on the Mount" has doubtless puzzled many a chemist, for salt without savour is as much an anomaly as a smile without a face.

Last summer, while spending my vacation at the seashore, I came across an old-fashioned "salt works," where common salt is prepared by evaporation of sea water, partly by means of trickling it over masses of brush and further by solar evaporation in shallow vats.

It was while investigating the process that I came upon what seems to me to be a plausible explanation of the scriptural passage, and at the same time I secured a quantity of the material called by the salt makers "salt lime," which is the subject of this paper.

It seems that the first solid product to separate from the sea water upon concentration by evaporation is a very slightly soluble, white, crystalline substance, which gathers in the first four or five shallow vats. These are provided, so that the tasteless, gritty substance may not come down along with the salt and constitute an undesirable impurity in it. This tasteless substance is "salt lime."

As to the connection between this substance and the salt which had lost its savour, I think it very probable that the ancient salt makers omitted to provide separate vats for the first, very slightly soluble product, and that as a result it got mixed up with their salt. Then, possibly, owing to exposure to moisture, the real salt may have become dissolved away from this less soluble part in certain instances, and the residue, being tasteless, would naturally be supposed to have "lost its savour," by the unscientific mind of that time.

Having secured eight or ten pounds of salt lime, I made an examination of the substance to determine its nature.

In physical appearance it is grayish white in color, crystalline in struc-

ture and it forms a layer about one-quarter inch thick as scraped from the evaporators. I was told by the owner of the salt works that not over thirty or forty bushels were obtained from the evaporation of an amount of sea water that would yield 5,000 bushels of salt; so it will be seen that the substance represents a high degree of concentration as the average per cent. of common salt in sea water is only 2.61 per cent.* and the amount of "salt lime" obtained is only about 1 per cent. of that of the common salt.

This high degree of concentration has led me to investigate the substance to see if it possesses any radio-activity, as, owing to the wide distribution of radio-active material more or less of it must find its way into the ocean, and, judging from the position of radium in the periodic system, the salts of radium ought to be found as sulphates among the less soluble constituents of the ocean water.

Experiments are now under way with a view to still further concentrate the material and to find whether it contains any trace of radio-active material.

Upon consulting the literature to which I have had access, I find that mention is made in nearly all cases of the separation of gypsum ($CaSO_4$, $2H_2O$) prior to the separation of common salt in the evaporation of both sea water and natural brines from wells.

I have conducted a qualitative analysis of the salt lime in the regular way and find that it does consist mainly of gypsum. It has the water of crystallization and gives the reactions of Ca and $SO_4$. It gives, moreover, evidence of the presence of a small amount of carbonate of calcium. I have seen no mention of this last fact in the literature to which I have had access. In order to determine the proportion of carbonate in the mixture I pulverized about 20g. in an agate mortar until it had all passed through a 100-mesh sieve; then taking a "fair sample," as in assaying, I weighed out 5.6623 grams into a Schrötter apparatus and determined the weight of $CO_2$ lost, in the usual manner.

The weight of $CO_2$ lost was .0156g, indicating a weight of .4354g of $CaCO_3$ (calculated) or .62 per cent. $CaCO_3$. A second determination gave .71 per cent.

I have tested carefully for Ba and Sr, using the ordinary form of chemical spectroscope as well as the regular analytical tests, and have

*New International Encyclopoedia, p. 723. 3.5 parts solid in 100. 77.76 per cent of solid is salt.

found no trace of either. I have also tested for $PO_4$ and fluorine with negative results.

On heating a sample of the salt lime in a dry test tube, there was a slight charring, possibly due to a slight amount of material from the wooden vats or perhaps from sea algae. There was also a slight smell of $NH_3$ on boiling a large mass of the finely-powdered substance with excess of NaOH in an attempt to remove $CaSO_4$ to secure concentration of the less soluble constituents. This was probably also due to small amounts of remains of sea algae.

From my study of the substance I would conclude that it consists mainly of gypsum, but that it contains an appreciable amount of $CaCO_3$ (.65 per cent.) and that it is remarkably free from other constituents, due probably to the sharp distinctions in solubility between the less soluble and the more soluble constituents of sea water. I hope to concentrate further a considerable amount of the substance and examine it for traces of radioactive material or other constituents.

# The Effect of Sugar on Sourness.

P. N. Evans.

It is common experience that some foods and beverages taste less sour when sugar is added, and it seems worth while to seek an explanation of the fact.

In books of popular science the statement is sometimes made that the sugar "neutralizes" the acid—in some such way, presumably, as a base might. This explanation is untenable from the chemist's standpoint, inasmuch as sugar enters into no such reaction with acids.

Better informed writers sometimes aver that since sugar can not neutralize acids its value in such cases is only imaginary and not real. Since, however, in matters of taste, if the imagination is satisfied the problem is practically solved, it becomes of interest to know *how* the imagination is satisfied in this instance.

Sourness is now known to be a property of the hydrogen ion; for all acids, and acids only, are sour, and all have this constituent, and this only, in common, when dissolved in water. A diminution in intensity of sourness must therefore be due either to a reduction in the number of hydrogen ions in a given volume of the solution, or to a lessened sensitiveness to sourness on the part of the nerves of taste.

An investigation was made by the writer as to whether the introduction of sugar diminished the degree of ionization of hydrochloric acid in a given solution, using the freezing point method, and it was found that there was no effect, the degree of ionization of the acid being the same in the presence and in the absence of sugar.

The value of sugar, then, must depend on its physiological effect on the nerves of taste, not on any chemical action by which the concentration of hydrogen ions is reduced.

Some years ago Professor T. W. Richards of Harvard University (Am. Chem. Jour. *1898*, 121), called attention to the delicacy of the sense of taste in detecting sourness and in comparing it in different intensities. With the assistance of Miss Carrie Richardson (now Mrs. C. E. Roth) the writer

made a series of over four hundred experiments in detecting acid in the presence and in the absence of sugar.

The experiments were conducted as follows: Solutions of hydrochloric acid of known strength were prepared, and equivalent solutions of sodium hydroxide were added gradually, the solution being tasted after each addition until sourness disappeared. In other experiments the acid was added to the alkali until sourness was noticeable. Both methods proved about equally delicate. As long as the solution was strongly acid or alkaline, only a drop or two was introduced into the mouth, but when the neutral point was almost reached a cubic centimeter of liquid was used and held in the mouth for a few seconds. The graduations of the burettes were hidden during every titration, that the judgment might not be prejudiced.

Experiments were made with solutions of acid varying from 0.715 normal to 0.0143 normal, or solutions containing 0.715 to 0.0143 milligrams of hydrogen ions per cubic centimeter. Sugar was added in quantities ranging from 0.04 to 0.8 grams per cubic centimeter.

With the experience gained in about twenty titrations considerable accuracy of taste had been acquired, so that consistent results were then obtained differing only about 1 part in 70 in a 15 cubic centimeter titration with the stronger solutions and in the absence of sugar, from those obtained with chemical indicators, the error being in almost all cases in the same direction, as might be expected—sourness disappeared with the addition of *less alkali* than the acidity as determined by phenolphthalein, or sourness appeared only on adding slightly *more acid* than required by the indicator. With the more dilute solutions, however, the *absolute* results were more exact. This is accounted for by the presence at the end point of less salt (due to the neutralized acid and alkali) in the more dilute solutions, the presence of salt reducing the delicacy of the sense of taste for sourness. With the most dilute solutions it was found possible to recognize with certainty the presence of 0.007 milligrams of hydrogen ions in the mouth, in 1 cubic centimeter of liquid, although 4 milligrams of salt were also present. In the most concentrated solution 0.01 milligrams of hydrogen ions was recognizable in the presence of 34 milligrams of salt.

The presence of sugar had the same effect as that of salt—the more sugar present in the solution the larger was the quantity of acid necessary for detection by taste; even the largest quantities of sugar used (0.8 grams per cubic centimeter) increased the necessary quantity of acid less than 1.5

times compared with that needed in the absence of sugar; 4.034 grams of salt was about as effective as 0.8 grams of sugar. In other words, if the mind is intent on noticing sourness, even large quantities of sugar do not seriously interfere. In the usual eating of sweet and sour food, however, the mind is, as it were, engrossed with the sensation of sweetness and rendered correspondingly less sensitive to other tastes.

In all probability any other powerful taste would be as effective in hiding sourness as sweetness is, but no other taste in concentrated form is so generally agreeable as sweetness. The sourness of lemonade would certainly be as thoroughly masked by highly salting it as by the addition of sugar: the result would not, however, be as agreeable to the majority of lemonade drinkers, probably.

In conclusion, brief reference might be made to a few experiments on the effect of sugar on bitterness, as sweetness and bitterness are commonly considered to be mutually exclusive terms—a thing can not be both sweet and bitter, though it can be at once sweet and sour. The experiments were made by the writer with mixtures of solutions of sugar and of quinine, but it was found impossible to obtain any numerical results, for, no matter what the proportion within very wide limits, the sensation of sweetness *preceded* that of bitterness, the mixture tasting sweet at the first moment and then bitter, the latter sensation being very lasting.

The use of sugar, then, to render sourness less intense, is based on a physiological, not on any chemical effect; the nerves of taste are less sensitive to one kind of taste in the presence of another, though the mind by concentration can largely overcome this obscuring effect.

# A Simple Method of Measuring Hydrolysis.

George A. Abbott.

Several methods of measuring the degree of hydrolysis of dissolved salts have been proposed from time to time; e. g., the measurement of the rate at which the solution saponifies an ester, such as ethyl acetate; the rate of hydration of milk sugar; and the measurement of the partial pressure of ammonia gas over solutions of its hydrolysed salts; but none of these methods is precise, and even under the most favorable conditions, they are far from satisfactory. The first is based upon the bold assumption that the rate of saponification is proportional to the concentration of the hydroxyl ions, and that it is unaffeced by the presence of other molecular aggregates; the second method involves a similar assumption; while the last is of little if any practical value, owing to experimental difficulties.

The method about to be described was developed in the course of an extended research on the dissociation relations of Ortho and Pyro Phosphoric Acids and their salts, which will be published in detail elsewhere. It is simple and convenient, and should be capable of a fairly wide application to the ammonium salts of other weak acids; therefore it has seemed sufficiently interesting to justify a brief description at this time.

When an aqueous solution of ammonia is shaken up with chloroform, the ammonia distributes itself between the two non-miscible solvents, and the distribution ratio is constant at a given temperature. Fortunately this ratio is of a magnitude which makes it possible to determine the concentration of the ammonia in the aqueous solution by simply titrating a measured volume of the chloroform with which the solution is in equilibrium. It is obvious that we may take advantage of this fact to determine the concentration of the free ammonia in a solution of its hydrolysed salt, and thus determine the degree of hydrolysis. It is free from assumptions and is as direct as a chemical analysis itself.

But, simple in principle as the method appears, its successful application requires attention to certain experimental details. The chief difficulty arises from the fact that the ammoniacal solutions form emulsions with the chloroform layer which remain turbid even after standing several hours in

the thermostat. Drops of the aqueous solution of variable size thus remain suspended in the chloroform layer, making it impossible to obtain concordant results when different samples are titrated. Fortunately this difficulty may be easily overcome by merely rotating the solutions in glass-stoppered bottles in the thermostat. For this purpose the bottles are fastented to the axle of the rotary stirrer of the thermostat after the familiar method of making solubility measurements, and allowed to rotate several hours (one to three), when the two phases invariably separate perfectly clear, with a sharply defined bounding surface. In order to establish the equilibrium between the solution of the hydrolysed salt and the chloroform, the latter is vigorously shaken with the aqueous solution in a stoppered separatory funnel. The phases are allowed to separate, after which the water layer is removed as completely as practicable, and another portion of the solution is added. This process is repeated until three portions have been shaken up with the chloroform; a fourth portion is then rotated with the chloroform, at a constant temperature, as described above. It is important to remove the sample of chloroform for titration without contamination by any of the aqueous solution. This may be easily done by means of a syphon. The short limb of the glass tube is sealed in the flame, and a small thin bulb blown on the end. It may then be passed, closed, through the aqueous layer, and opened by breaking against the bottom of the bottle. The chloroform is syphoned into a clean, dry, vessel, measured, and titrated with 0.02 Normal hydrochloric, or nitric, acid, using methyl orange as indicator. Enough pure water should be added to make a layer of convenient depth to view the color of the indicator; since the latter does not enter the chloroform, and the stoppered vessel should be vigorously shaken at intervals during the titration.

The distribution coefficient of ammonia between chloroform and water was measured, at 18°, at concentrations 0.1, 0.05, and 0.02 Normal, and the mean of eight measurements gave 27.36. This is the ratio of the concentration of the undissociated ammonia in the aqueous solution to the concentration of the ammonia in the chloroform.

The method was applied to the measurement of the degree of hydrolysis of $Na_2NH_4PO_4$, at 18°, and concentrations 0.1, 0.05, and 0.02 molal, with the following results:

| *Conc. Mols. per Litre.* | *Per Cent. Hydrolysis.* |
|---|---|
| 0.1 | 95.39 |
| 0.05 | 95.44 |
| 0.02 | 95.65 |

That is, in a solution of $Na_2NH_4PO_4$, at the above concentration, only 5 per cent. of the ammonia is chemically combined. When the hydrolysis is large the method is accurate, and even when it is small the results are good, as shown by the following values for the salt $NaNH_4HPO_4$:

| *Conc. Mols. per Litre.* | *Per Cent. Hydrolysis.* |
|---|---|
| 0.1 | 2.98 |
| | 2.92 |
| | 2.98 |
| 0.05 | 3.02 |
| | 3.13 |
| | 3.02 |
| | 2.90 |
| | Mean, 3.0 |

These values are corrected for the ionization of the ammonia at the different concentrations.

# The Ionization of the Successive Hydrogens of Ortho-phosphoric Acid.

George A. Abbott.

The dissociation relations of polybasic acids are at present imperfectly understood. Owing to the natural complexity of the compounds and the experimental difficulties due to hyrolysis, hydration, and possibly association in solution. few investigators have attempted to determine the dissociation constants of the different hydrogens of these acids; but the recent development of physico-chemical methods of investigating the nature of dissolved substances has made the solution of such problems appear entirely practicable. Therefore an extended investigation was undertaken, at the suggestion of Prof. A. A. Noyes, in the hope that an exhaustive study of the dissociation relations of the phosphoric acids might contribute toward a better understanding of their chemical behavior in inorganic reactions. This investigation was conducted in the Research Laboratory of Physical Chemistry of the Mass. Inst. of Technology.

In this paper I shall attempt to present briefly only a few results, in the hope that they may prove sufficiently interesting to justify their presentation. The method of measuring hydrolysis described in the previous paper gives us at once a reliable means of determining the dissociation constants of weak acids. When both acid and base are weak (slightly dissociated), the following relation holds:

$$\frac{h^2}{(1-h)^2} = \frac{K_W}{K_A K_B}$$

in which $h$ denotes the degree of hydrolysis of the salt, and Kw, $K_A$ and $K_B$ are the dissociation constants of water, the acid and the base, respectively. They are defined by the following expressions of the Mass Action Law:

$$K_W = C_H \times C_{\bar{OH}}$$

$$K_A = \frac{C_H \times C_{\bar{A}}}{C_{HA}}$$

$$K_B = \frac{C_B \times C_{\bar{OH}}}{C_{BOH}}$$

The dissociation constants of the successive hydrogens of Orthophosphoric Acid will be designated $K_1$, $K_2$ and $K_3$. They are defined by the Mass Action equations:

$$K_1 = \frac{H \times H_2PO_4}{H_3PO_4}$$

$$K_2 = \frac{H \times HPO_4^{=}}{H_2PO_4}$$

$$K_3 = \frac{H \times PO_4^{\equiv}}{HPO_4^{=}}$$

They will be considered in inverse order.

$K_3$ may be determined by substituting the value of *h*, obtained by the partition method, in the hydrolysis equation.

$h = .95.$
$Kw = 8 \times 10^{-15}$ (mols. per litre).
$K_B = 1.72 \times 10^{-7}$.

$$\frac{(.95)^2}{(1. - .95)}2 = \frac{50 \times 10^{-16}}{(K_3)(1.72 \times 10^{-7})} \text{ whence,}$$

$K_3 = 6.48 \times 10^{-13}$ (mols. per litre).

$K_3$ was also determined by an utterly independent method based upon the measurement of the increase of electrical conductivity produced on adding to solutions of $Na_2HPO_4$, varying amounts of ammonia. Time will not permit a description of the method and calculations which are somewhat complicated, but the values obtained at different concentrations agreed remarkably well with the above value.

In like manner $K_2$ may be calculated from the hydrolysis of $NaNH_4HPO_4$. The value obtained by substitution in the above equation is $K_2 = 3.9 \times 10^{-7}$, but this calculation fails to take into account the influence of the unionized substances in the solution.

The correction involves merely the application of the Mass Action Law, and the principle that, in a mixture of salts with a common ion each salt has the same degree of ionization as if it were present alone at a concentration equal to the sum of the concentration of the two salts. However, the algebra involved is not particularly entertaining, and it will perhaps be sufficient to give the mean corrected value of $K_2 = 2.09 \times 10^{-7}$. It is then seen that the correction is large. The value of $K_3$, when corrected for the influence of unionized substances becomes $K_3 = 5.55 \times 10^{-13}$.

The hydrolysis of the salt $NH_4H_2PO_4$ is too small to be measured by the

partition method, for the ionization of the first hydrogen of Orthophosphoric Acid is fairly large. It does not accurately obey the Mass Action Law: hence $K_1$ has no definite meaning. However, the degree of dissociation was determined from the values of the electrical conductivity of the acid and its salts, and other known data, and the following values were obtained, at 18°C:

| *Conc. Mols. per Litre.* | *Degree of Ionization.* |
|---|---|
| 0.1 | 0.286 |
| 0.05 | .364 |
| 0.01 | .602 |
| 0.002 | .839 |
| 0.0002 | .965 |

Ostwald's Dilution Law requires that

$$\frac{Cr2}{1-r} = K_1$$

wherein C represents the concentration and $r$ the degree of ionization. Substituting the values of $r$ we obtain, for the values of $K_1$ at the different concentrations:

| *Concentration.* | *K.* |
|---|---|
| 0.1 | 0.0114 |
| .05 | .0104 |
| .01 | .0091 |
| .002 | .0087 |
| .0002 | .0053 |

and it is seen that the deviation from the law is marked.

A comparison of the ionization constants of phosphoric acid with those of some other acids is interesting.

| | $K \times 10^{10}$ |
|---|---|
| **Acetic Acid, $C_2H_3O_2$ — H** | 180,000. |
| **Carbonic, $HCO_3$ — H** | 3,040. |
| **Hydrosulphuric, HS — H** | 570. |
| **Boric, $H_2BO_3$ — H** | 17. |
| ***Phenol, $C_6H_5O$ — H** | 1.3 |
| **Phosphoric Acid, $K_1 = H_2PO_4$ — H** | 100,000,000. (Approx.). |
| **" " $K_2 = HPO''4$ — H** | 2,090. |
| **" " $K_3 = PO'''\ 4$ — H** | 0.00555 |

*These values are taken from Walker, "Zeit Phys. Chem." 32, 137, 1900.

The first hydrogen of ortho phosphoric acid behaves in a manner analogous to that of the strong acids; the second to that of a weak acid intermediate between carbonic and hydrosulphuric; while the third is even weaker than phenol. This accounts for the well-known behavior of the acid toward indicators.

# Coefficient of Expansion of Brick.

C. V. Seastone.

Inasmuch as brick is used extensively as a building material in different ways and in different types of construction, and also beacuse it is used to a large extent as a paving material, a knowledge of its physical properties is of value. With a view to increasing this knowledge a series of experiments were made at Purdue University to determine the coefficient of expansion of different grades of brick. It is the purpose of this paper to give the results of these experiments.*

The method used to determine the coefficient was to subject a bar of steel whose coefficient of expansion was known, and the specimen of brick, to identical changes of temperature. The difference of expansion was measured by the principal of the optical lever. This difference reduced to unit length and unit temperature gave a correction to apply to the coefficient of the metal bar.

The apparatus used for these experiments was designed by Professor W. D. Pence, former Professor of Civil Engineering at Purdue University, and used by him to determine the coefficient of expansion of concrete. It consists of, first, the specimen to be tested; second, the bar of steel of known coefficient; third, a heating apparatus, consisting of a double-walled steam jacket through which the mirror of the optical lever could be seen; fourth, a rod in the opposite side of the room, whose image, reflected in the mirror, was read by means of an engineer's level. The thermometer is hung inside the heater and is read through the glass door by the aid of an incandescent lamp suspended alongside of it. The lamp is turned on only for an instant in order not to affect the reading of the thermometer. Both the level and the steam jacket were mounted upon a concrete foundation. The arrangement of the apparatus and the method of conducting the experiment will be easily understood from the figure.

*The experiments were conducted, under the writer's direction, by W. J. Burton and C. W. Wilson (1902-1903), and by G. W. Case and G. C. Curtiss (1904-1905), as thesis work in the School of Civil Engineering, Purdue University.

Three qualities of brick were used. First, a good quality of No. 1 paving brick; second, a medium quality of No. 2 paving brick; third, a soft quality of ordinary building brick. The brick were approximately 2"x4"x8" in dimension and were cemented together in order to obtain the specimen of desired length.

Following is the mean value obtained for each of the above qualities of brick:

No. 1 brick (hard) Coefficient of Expansion per degree F = .00000401.

No. 2 brick (medium). Coefficient of Expansion per degree F = .00000401.

No. 3 brick (soft). Coefficient of Expansion per degree F = .00000393.

It will be noted that the hardness of the brick has little to do with the amount of expansion, the three qualities giving essentially the same values.

# Contributions to the Knowledge of Vehicle Woods.

W. K. Hatt.

It is admitted by both the forester and the manufacturer of vehicles that the supplies of hickory and like woods used in vehicle construction are becoming scarce. The quality is poorer and the price is higher each succeeding year. Indeed, the condition with respect to the supply of vehicle woods may be said to have become acute, and the various trade organizations have become aroused to such an extent that meetings have been held to discuss means of increasing the sources of supply and economizing on the construction.

Three ways in general are open:

First, an endeavor may be made to determine the availability of new species as substitutes for such woods as hickory and white oak.

Second, planting operations might be made a success.

Third, a more economical use may be made of the timber supplies now entering the mills for manufacture into wagon parts.

The present paper discusses lines of effort in the substitution of new and untried species, and in improving rules of grading in the mills so that excellent material, fully available for service, may not be thrown out, as is the case now, by incorrect rules of grading.

The Forest Service, United States Department of Agriculture, and the Purdue University Laboratory have for some years co-operated in the establishment of a timber testing station in the Laboratory for Testing Materials of Purdue University, at which studies have been made to determine the essential mechanical properties of various species of wood, and what effect various factors have upon these properties. Other studies to determine the correctness of the rules of grading for vehicle parts, and to examine into the merits of different designs of such parts as wagon axles, and to investigate the properties of possible substitutes, have a direct application to an important industry of the State. This Laboratory at Purdue University is one of a series of laboratories operated by the Forest

Service at such institutions as the Yale Forest School, and the Universities of California, Oregon and Washington. The writer of this paper has been in charge of this work since is inception in the year 1903.

### SUBSTITUTION OF NEW SPECIES.

The practice of substituting cheaper and weaker species for others which have become scarce and high priced has been increasing for some time. For instance, longleaf pine harvester poles have come into use in place of oak poles, and those parts of vehicles not bearing a great strain are now made of weaker woods. The successful introduction of species which are quite proper for the service is generally retarded by prejudice. Consumers have demanded certain species regardless of their actual fitness, and irrespective of the fact that other and cheaper woods might answer the purpose equally well. For instance, both poplar and red gum, which are now held in such high estimation, have both had to fight their way for a place on the market for such parts as wagon box boards.

It may be stated at the outset that there is probably none of our eastern species that can replace hickory for strength and general shock-resisting properties and permanence of shape after it is bent. The lines of endeavor must be to use hickory in only such parts of the wagon where great shock-resisting properties are required, and to correct the rules of grading so that minor defects which do not affect the strength of the wagon are not allowed to operate to throw a suitable piece of hickory out of use. A recent study of the properties of the eucalypts in California by the Forest Service seems to point to the value of some of these species for use in wagon construction. The blue gum (Eucalyptus globulus) is the most common species in California, and has competed with black locust for insulator pins, and has given satisfactory service in chisel and hammer handles, and has been used locally for wagon tongues, axles, shafts, spokes, hubs and felloes in California. The wood is hard, strong and tough, and grows very fast. In bending the modulus of rupture is 23,000 pounds per square inch for seasoned lumber, about equivalent to second-growth hickory. This eucalypts seems to be the most promising species upon which to draw for products requiring great strength, toughness and hardness.

### GRADING RULES.

An instance of the method of attack to determine the correctness of the grading is in the case of hickory wagon spokes, which are now graded

into six divisions: A, B, C, D, E and Culls. Five hundred spokes were procured from the Bannister Wheel Company of Muncie, Ind., and were tested under a direct load as shown in the diagram, and the maximum load, together with the amount of bending sidewise before fracture was noted. This combination of maximum load and amount of side bending gives a factor which represents toughness and shock-resisting capacity. The results from the spoke tests show more than 50 per cent. error in the present grading system, which is largely due to the traditional prejudice and consequent discrimination against red hickory. No red spokes are now allowed in the A and B grades, yet these tests show that a large proportion of the red spokes now included in the lower grades should be, because of their strength and toughness, included in the highest grades. It appears, also, that weight for weight, the red spokes and the mixed red and white spokes, are fully as strong as the entirely white spokes. These tests will be supplemented by tests on various hickory buggy shafts containing typical defects. Such tests have an interest not only to the genral public, in that a drain on a limited class of material is somewhat decreased, but they have an interest also to the grower of timber, because they increase the market value of a considerable portion of the product of the forests.

Tests have also been made on a number of wagon axles. Various species of woods, not only from the western forests, but from eastern forests, have been made up into axles at a mill and have been submitted to the laboratory for test. At the present time the series is complete upon hickory and maple axles of three different designs, and the method of attacking the problem and of determining the qualities of the axles by actual test will be of interest from a scientific standpoint. (Referring to the photograph of an axle under test, the method of loading and measuring and the behavior of the axle is shown in detail, and the various quantities entering into an estimation of the value of the axle are explained.)

Another example is in a series of tests to determine the proper grading of pine harvester poles. A large part of this material is shipped up from the south to such markets as Chicago, and is there graded by the manufacturers, the defective material being thrown out at a loss to the shipper, not only of the cost of the material, but of the freight. It becomes important, therefore, to know whether the poles thrown out might be used. Poles containing different classes of defects were tested, and it was found that at the present time there is an unjustifiable prejudice against the use of poles containing a considerable per cent. of sapwood.

Another series of tests on the relative strength of oak and yellow pine wagon poles is of interest, not only for the method of loading and measuring the quality of the pole, but from the light it throws on the essential difference between products from such woods as oak and such woods as yellow pine. (Referring to the diagram, the method of loading and measuring the various elements of the test were shown. The general results of the investigation are also shown by the diagram and table, from which it appears that while longleaf pine poles are as strong and elastic as the oak poles, yet they lack the toughness, and the effect of a cross grain is much more serious than in the case of oak.)

These various instances are brought forward to show the method of attack and scientific care in aiding the solution of a large commercial problem of this kind. The results of these tests will appear in a publication by the Forest Service.

# Notes Upon the Rate of Tree Growth in Glacial Soils in Northern Indiana.

Stanley Coulter.

The clearing of certain small timber areas near Lafayette in January and February, 1906, gave an exceptional opportunity for studying the rate of growth of certain native species of trees. The species occurring in sufficient number to warrant deductions were the white oak, red oak and black walnut. Of the red oak forty-nine trees were examined; of the white oak, sixty, and of the black walnut, thirty-two. It was assumed that the annual rings gave a fair indication of the age, despite the occasional formation of two rings in a single year, or the apparent suppression of an annual ring because of exceptionally unfavorable conditions, which were recognized as possible contingencies. In the forms examined neither of these conditions were indicated, the growth in each case having apparently proceeded in an orderly and orthodox fashion.

The measurements are the averages of the longest and shortest diameters and were taken inside of the bark. Both the measurements and the counting of the rings were made by four groups of students, insistence being placed upon accuracy. In cases of discrepancy a recount or remeasurement, or in some cases both, was directed. The tables, therefore, may be considered as exceptionally accurate, each specimen having been independently studied by four groups working on different days.

The oaks, with but few exceptions, occurred on the highest levels, just northwest of Purdue University. The general surface is rolling, with a southeastern exposure, more or less interrupted by ravines formed by small streams. Approximately the topographical conditions were the same.

The soil in the area under consideration is relatively thin. It consists of a few inches of humus made up of the usual forest material; a few inches (8-12) of a loam soil more or less alluvial in character, followed by perhaps a foot of fairly heavy clay. Underlying this is the glacial drift, extending downward from one hundred and ten to one hundred and twenty feet to the bed of the river. The drift in this region is mainly sand and

gravel, with a few thin seams of light clay at various levels. Throughout the area from which the oaks were cut, the soil overlying the drift material ranges from eight to twenty-three inches in thickness. So far as the physical and chemical composition of the soil is concerned we have practically identical conditions over the entire area.

The black walnut was cut for the most part in an area lying in the second river terrace, where, in addition to the forest humus, there occurs from three to five feet of alluvial soil before the clay is struck. The clay also in this area is perhaps twice as thick as in the former case. The terrace has an eastern exposure, while the curves of the river protect the particular tract in question from the north winds, but leave it open to winds from the south. Upon the west it is protected by the escarpment of the upper terrace. The area covers but a few acres and evidently furnishes as uniform conditions as can be found in nature. The two tracts present, however, fairly distinct conditions, a fact which should be borne in mind in any comparison of the rate of growth.

The measurements of the different species are given in tabular form as furnishing in the main the data for the deductions drawn later in this paper. Possible occasional errors may occur in the computation of percentages in spite of the fact that the figures have been reviewed three times.

From the tables it is shown that in the area indicated and under the conditions outlined the average yearly increase in white oak, based upon sixty specimens, was .1995 of an inch; of red oak, based upon forty-nine specimens, was .22674 of an inch; of black walnut, based upon thirty-two specimens, was .27712 of an inch.

A number of interesting inferences seem plain.

1. There is a wide range in the growth rate in trees of the same species, even when growing under the same conditions. Thus the range in white oak is from .095 to .328 of an inch; in red oak, from .134 to .515 of an inch; in black walnut, from .195 to .358 of an inch. Such wide range under conditions so nearly identical must be referred to individual idiosyncracies, probably referable in most cases to the vigor of the acorn, to the character of the tree from which the acorn was derived, to inherited growth tendencies or similar causes. An examination of the table of trees of similar age in respect to their diameters will show clearly this "personal equation" of the tree. For example, in Table II, numbers 38 to 45, inclusive.

TABLE I. QUERCUS ALBA.

| Serial Number. | Inches Diameter. | No. of An. Rings. | Average Yearly Increase. |
|---|---|---|---|
| 1 | 32 | 200 | .160 |
| 2 | 11 | 68 | .162 |
| 3 | 11 | 74 | .149 |
| 4 | 16 | 76 | .210 |
| 5 | 22 | 78 | .282 |
| 6 | 13 | 66 | .196 |
| 7 | 19 | 60 | .317 |
| 8 | 17 | 74 | .230 |
| 9 | 15.5 | 74 | 209 |
| 10 | 17 | 76 | .223 |
| 11 | 17 | 79 | .215 |
| 12 | 17 | 77 | .220 |
| 13 | 16.5 | 74 | .223 |
| 14 | 15 | 75 | .200 |
| 15 | 13 | 77 | .170 |
| 16 | 12.5 | 75 | .166 |
| 17 | 15 | 77 | .195 |
| 18 | 15.5 | 77 | .201 |
| 19 | 13.5 | 78 | .173 |
| 20 | 21.5 | 80 | .269 |
| 21 | 16 | 79 | .202 |
| 22 | 20 | 77 | .260 |
| 23 | 13 | 77 | .169 |
| 24 | 19 | 77 | .247 |
| 25 | 19 | 75 | .253 |
| 26 | 47 | 303 | .155 |
| 27 | 9 | 63 | .143 |
| 28 | 12 | 73 | .164 |
| 29 | 16 | 78 | .205 |
| 30 | 17 | 89 | .191 |
| 31 | 15 | 78 | .192 |
| 32 | 24 | 252 | .095 |
| 33 | 12 | 75 | .160 |
| 34 | 12 | 75 | .160 |
| 35 | 50 | 243 | .206 |
| 36 | 28 | 185 | .151 |
| 37 | 28 | 180 | .155 |
| 38 | 31 | 222 | .140 |
| 39 | 26 | 232 | .112 |
| 40 | 30 | 230 | .130 |
| 41 | 18.5 | 72 | .257 |
| 42 | 18.5 | 77 | .240 |
| 43 | 25 | 76 | .328 |
| 44 | 14 | 73 | .191 |
| 45 | 13.5 | 77 | .175 |
| 46 | 20 | 77 | .261 |
| 47 | 16 | 79 | .202 |
| 48 | 20.5 | 81 | .253 |
| 49 | 13.5 | 76 | .177 |
| 50 | 15.5 | 78 | .200 |
| 51 | 14.5 | 73 | .200 |
| 52 | 13 | 76 | .171 |
| 53 | 13 | 76 | .171 |
| 54 | 17 | 75 | .226 |
| 55 | 41 | 208 | .197 |
| 56 | 15.5 | 80 | .194 |
| 57 | 17 | 76 | .223 |
| 58 | 17 | 79 | .215 |
| 59 | 17.5 | 78 | .223 |
| 60 | 16.5 | 78 | .211 |

TABLE II. QUERCUS RUBRA.

| Serial Number. | Inches Diameter. | No. of An. Rings. | Average Yearly Increase. |
|---|---|---|---|
| 1 | 20 | 76 | .263 |
| 2 | 15 | 78 | .192 |
| 3 | 14 | 77 | .182 |
| 4 | 15 | 77 | .193 |
| 5 | 14.5 | 75 | .193 |
| 6 | 24 | 77 | .311 |
| 7 | 22 | 78 | .282 |
| 8 | 22 | 83 | .265 |
| 9 | 20 | 82 | .244 |
| 10 | 19 | 82 | .231 |
| 11 | 16.5 | 82 | .201 |
| 12 | 15 | 82 | .183 |
| 13 | 17 | 82 | .207 |
| 14 | 15 | 82 | .183 |
| 15 | 9.5 | 76 | .125 |
| 16 | 15 | 80 | .187 |
| 17 | 23 | 73 | .315 |
| 18 | 14.5 | 77 | .188 |
| 19 | 12 | 87 | .138 |
| 20 | 15.5 | 115 | .134 |
| 21 | 14.5 | 76 | .190 |
| 22 | 15.5 | 90 | .172 |
| 23 | 13.5 | 78 | .173 |
| 24 | 13 | 71 | .183 |
| 25 | 11.5 | 74 | .155 |
| 26 | 15 | 63 | .238 |
| 27 | 14.5 | 76 | .190 |
| 28 | 16 | 73 | .219 |
| 29 | 22.5 | 81 | .277 |
| 30 | 16 | 70 | .228 |
| 31 | 14.5 | 72 | .201 |
| 32 | 24 | 88 | .272 |
| 33 | 20 | 64 | .312 |
| 34 | 22 | 79 | .278 |
| 35 | 20 | 71 | .281 |
| 36 | 22 | 71 | .310 |
| 37 | 33 | 64 | .515 |
| 38 | 22 | 82 | .268 |
| 39 | 18.5 | 82 | .225 |
| 40 | 20 | 82 | .243 |
| 41 | 19 | 82 | .231 |
| 42 | 15 | 82 | .182 |
| 43 | 17 | 82 | .207 |
| 44 | 15 | 82 | .182 |
| 45 | 16.5 | 82 | .201 |
| 46 | 13.5 | 61 | .221 |
| 47 | 11 | 60 | .183 |
| 48 | 23 | 73 | .315 |
| 49 | 18.5 | 82 | .225 |

TABLE III. JUGLANS NIGRA.

| Serial Number. | Inches Diameter. | No. of An. Rings. | Average Yearly Increase. |
|---|---|---|---|
| 1 | 25 | 82 | .306 |
| 2 | 14 | 64 | .219 |
| 3 | 15 | 77 | .195 |
| 4 | 19 | 73 | .260 |
| 5 | 18 | 67 | .270 |
| 6 | 21 | 81 | .260 |
| 7 | 19 | 58 | .327 |
| 8 | 20 | 64 | .312 |
| 9 | 18 | 76 | .237 |
| 10 | 20 | 74 | .270 |
| 11 | 14 | 52 | .270 |
| 12 | 15.5 | 68 | .228 |
| 13 | 21.5 | 64 | .336 |
| 14 | 21 | 72 | .291 |
| 15 | 22.5 | 71 | .317 |
| 16 | 20 | 66 | .303 |
| 17 | 24 | 67 | .358 |
| 18 | 15 | 45 | .333 |
| 19 | 22.5 | 88 | .255 |
| 20 | 18 | 74 | .243 |
| 21 | 19 | 76 | .250 |
| 22 | 20 | 70 | .285 |
| 23 | 20 | 78 | .256 |
| 24 | 24 | 80 | .300 |
| 25 | 17 | 63 | .270 |
| 26 | 16 | 60 | .266 |
| 27 | 23 | 74 | .311 |
| 28 | 23 | 80 | .287 |
| 29 | 22 | 77 | .285 |
| 30 | 22 | 83 | .265 |
| 31 | 19 | 79 | .240 |
| 32 | 20 | 75 | .266 |

are of the same age and grew on a gentle northward-facing slope in an area of less than an acre, yet the diameters range from 15 to 22 inches.

2. Conclusions as to the rate of growth of various species, which fail to take into account individual variations are manifestly misleading. This variation may reach as much as 25 to 30 per cent. above or below the average growth rate. Incidentally it gives strong emphasis to the necessity of great care in the selection of seeds for cultural work—since a careful selection may increase the wood crop to the extent of 25 per cent. beyond the average.

3. The growth rate in the area examined was exceedingly slow, especially in the case of the oaks. In a report of W. F. Fox, Superintendent of State Forests, New York, it is stated that a vigorous three-inch white oak sapling would, under favorable conditions, at the end of twenty years at-

tain a diameter of eleven inches, or make a net gain of eight inches. This would give an average yearly increase of .4 of an inch, which is considerably greater than the highest yearly increase in any of the sixty specimens examined, or .328 of an inch. Mr. Fox also states that a three-inch red oak sapling would, in twenty years, attain a diameter of thirteen inches, thus making a net gain of ten inches. This gives a yearly rate of .5 of an inch, or more than double the average yearly rate (.22674 of an inch) of the forty-nine specimens examined. It is true that specimen 37 shows an average yearly growth of .515 of an inch, but the next is .336 of an inch and only six out of the forty-nine show an average yearly growth in excess of .3 of an inch. An examination of a number of white and red oak logs at local mills confirms the conclusion that the growth rate in the area studied is exceedingly slow.

It is probable that the cause of this slow growth is to be found in relatively thin soil underlaid by the hundred or more feet of drift. The sand and gravel of the drift constitute a natural filter which rapidly carries the soil water to lower levels. The thin soil and the stratum of clay can not hold sufficient water to carry the trees through our long summer drought and at the same time furnish a large amount of material for growth. Observation of the trees of the Purdue campus furnishes confirmation of this view. The soil conditions of the campus are practically the same as in the area studied. The older trees of the campus were set out between 1875 and 1880, and were largely maples and elms along the driveways, other forms being scattered through the grounds. The maples and elms are in sufficient numbers to justify a few generalizations. The trees show an early period of rapid growth, a period of slow growth and finally a practical cessation of growth. During this latter period the trees begin to show all the signs of what might be called senility. In the early years, the roots not having penetrated deeply, find sufficient available moisture in the thin soil to provide for the maintenance of the tree and its normal growth. A little later, the deeper penetrating roots reaching the drift find but little water, so little, indeed, that under the most favorable conditions provision can be made for only a slight growth. Still later the increasing demands of the tree can not be satisfied and it begins to age, and we have the case of elms and maples completing their life cycle in twenty-five or thirty years, attaining in the meantime a diameter of from ten to fifteen inches. The duration of life upon the campus is much less that in forest conditions, be-

cause of the absence of the forest floor and of its work in the conservation of moisture and the enrichment of the soil.

4. It may be concluded that the most important factor in the growth of trees is *soil moisture.* A confirmation of this may be found in the conditions existing in areas of maximum development in number and size. According to Sargent. the hardwoods of the United States find their maximum development in numbers and size in the lower stretches of the Wabash Valley. In other words, in a region in which the soil possesses a rich water content.

In any forecasts as to the results of reforestation, or as to the rate of tree growth in any given locality the supreme factor to be considered is the constancy of the water content of the soil.

5. In the case of the oaks an examination of the table will show a period of rapid growth, a period of slower growth and finally a period of scarcely appreciable increase. In the case of the walnut the growth is much more uniform throughout the life of the tree. These are conditions that would be expected if conclusion three is at all correct.

6. It is probable that red and white oak in regions such as the one studied have reached their full size at from eighty to a hundred years, after which they begin to deteriorate. The few large forms introduced in the table are from the lowest river terrace and were introduced for purposes of comparison.

7. The growth habit of the tree seems to control more largely than external factors of growth. In a group of trees closely grouped the majority may show an exceptionally rapid growth in a given year, while one or two show but a small increase. That this might be due to insect defoliation or other causes is of course possible, but an examination of the growth through a series of years show a habit of slow growth as compared with other individuals, whatever may be the external conditions. On the other hand, individuals showing a habit of rapid growth are easily recognized. No observable differences in the proportion of spring and summer wood, in texture, in color or in any gross characters are to be observed in these differing forms. Some individuals of each species are rapid growers and some are slow growers, whatever may be the origin of the habit. It was impossible to determine whether or not this habit could be determined by external features, as the trunks had been sent to the saw mill before the area was found.

8. The conditions of the area described are fairly typical and apply

to a large part of the glaciated region of northern and northwestern Indiana. Of course the immediate valleys and terraces of rivers and streams furnish special conditions which must be considered as exceptional. It is probable that any extended study of the rate of growth of the species discussed in the region indicated will show results but slightly varying from those given above.

9. It is probable that under soil conditions such as those described, larger forms than those found today but rarely occurred. A careful examination over wide areas for old stumps of the virgin forest, showed that all of the large forms were found in alluvial soils and never by any chance in the thin-soiled uplands.

These studies are being extended to include many of our native species and arrangements have been made to increase the number of forms studied of the species discussed in this paper.

The exact knowledge of the rate of growth of various species under differing conditions is a matter of vital importance from the viewpoint of wood-lot forestry. It is scarcely less far reaching in its application and of scarcely less economic significance than a knowledge of forest utilization. If the conclusions here presented are warranted by the date very self-evident practical application necessarily follow. These, however, are not included in the scope of this paper, but will be presented later.

# The Michillinda (Michigan) Sand Dunes and Their Flora.

Stanley Coulter.

Nowhere is the struggle for a place in nature by plants more spectacular or more severe than that with the sand dunes. The alignment of the opposing forces is so evident, their activity is so ceaseless, their modes of attack so varied that one wonders that the plants ever succeed in fixing these restless masses of sand. After the classic studies of Cowles upon the Dune flora it would seem that little remains to be said, but to the botanist accustomed to the placid plant life of mesophytic regions the struggle is irresistibly fascinating and, as a rule, he is unable to resist the temptation of a new consideration of some phases of the problem.

The region studied was a short stretch of beach dunes on the east shore of Lake Michigan at a summer resort known as Michillinda, about twenty-five miles north of Muskegon. That the region is exceptionally favorable for such studies is evidenced by the fact that it is the place chosen by Dr. Cowles for his classes when considering the problems presented by the dune flora. The study made was neither systematic nor exhaustive; it was merely a part of a rest of three weeks after a summer school session. No attempt was made to enumerate the constituent members of the flora or to work out all of the factors determining the success or failure of the plant invaders. The paper, therefore, touches only the more evident features of the problem and treats even these in the line of suggestion rather than explanation.

The plants begin their struggle on what Cowles calls the middle beach, a region beaten by the winter waves, but as a rule dry during the summer months. The struggle here is almost hopeless and on the open stretches of the beach the plants are extremely scattered. In the shelter of the drift logs and debris, however, they are more numerous and may maintain a precarious existence for some months. It is probably the area of greatest stress. The fierce winter storms compel an absolute renewal of the struggle each succeeding year, while the summer winds and sun make it possible for only such plants as possess the most marked xerophytic characters to maintain themselves. A severe summer storm may overwhelm the beach,

killing all forms that have obtained a foothold, and the struggle must begin all over. Such a storm swept the Michillinda beach for almost a week during the past summer, blotting out absolutely the middle beach flora. In a week, however, the brave plants began to show themselves again and to renew the apparently hopeless struggle. The most notable member of this flora was the succulent leaved crucifer, *cakile edentula* (Bigel.) Hook. The adaptation in this case is plainly against the dessicating action of wind and sun. The plant also is able to withstand, to a certain extent at least, a sand covering of considerable thickness, forcing its way through it to the surface apparently but little injured by its temporary burial. Its stubborn erectness and unyielding rigidity are characters that at once serve to distinguish it from the other members of this flora.

More numerous upon this stretch of beach is *Cuphorbia polygonifolia* L. This prostrate spurge finds its protection in its close hugging of the sands which are here always damp at a slight depth, whatever may be the sun's heat. A covering of sand does not seem to kill it, unless it is several inches thick, new shoots emerging from the crown, finding their way to the surface in a few days. In spite of these two species, the middle beach strikes one as practically destitute of plants—and the wonder grows as the conditions are studied that the few that do occur have found even a temporary lodgment.

The upper beach and the active dune region present a much more varied and consequently much more interesting flora. The opposing forces here are the fierce rays of the sun, the almost constant winds and the shifting sands. In high winds the mechanical action of the sands is very great, often completely destroying well-established plants. These factors have led to the development of the most pronounced xerophytic characters found in this latitude, and this in spite of the fact that there is no scarcity of water in the soil. Even after the long summer drought, the sand is moist at a slight distance below the surface. The most marked adaptations in this region are those against the covering of the plant with sand, exposure of roots by the shifting of the sand, excessive evaporation because of sun and wind, and the mechanical action of the sand driven by storms. Practically every device against these destructive agencies is here in evidence. They are so well known that they need not be recited in this connection.

Most interesting, perhaps, are the provisions against submergence by the sands. In the case of the poplars, willows and dogwoods, the sprouting habit in connection with the habit of sending out roots from any node in

contact with the soil is sufficient protection, save in the most extreme cases. These plants, therefore, while not strongly developed in the upper beach, are rarely wanting on active dunes. The willows commonly found are *S. yuviatilis, gloucophyila* and *adenophylla*. The dogwoods are *C. stolonifera* and *Bailcyi*. The poplar is the cottonwood, *P. deltoides*. To the botanist, the adaptation of these plants for such a position are self-evident, but individual cases present continual variations. Nothing could more clearly illustrate the extreme plasticity of these shrubby species than their quick and sure response to these constantly varying factors.

These grasses lead in the attack upon the dunes. These plants all arise from a single root stock.

In the case of the grasses, which are chiefly *Andropogon, scoparius, Ammophila arenaria, Calamovilfa longifolia*, and *Elcymus canadensis*, there is a quick setting of roots from the nodes when there is but a partial submergence, while the long, horizontal branching root stock is constantly sending up new stools during the continuance of favorable conditions. The first plants to obtain a foothold upon these shifting sands are usually the grasses. From a single stool through the agency of the root stock there is a rapid spread which covers a very considerable area. In various places upon the most active portion of the dunes some one or more of these grasses obtain a foothold and struggle fiercely to maintain the place they have seized. So far as my personal observations go, the invasion of the dune is

made at its lower stretches, gradually creeping upward, until in a particularly favorable season the whole dune is fairly well covered with plants. The binding together of the soil by the grasses, even for a short time, is sufficient to permit the establishment of other forms, so that in places the flora of the upper beach and active dune may be quite varied. On the upper beach the most common of the plants are *Artemisia caudata* and *A. Canadensis*, while the attractive *Carduus Pitcheri* is scarcely less common. In these plants the strong and long tap-root and dissected leaves serve as an almost perfect protection against excessive evaporation and the mechanical

**At the close of a favorable season the whole dune may be fairly well covered with plants.**

action of the sand in the case of high winds. In the case of the Artemisias it was possible to observe in a considerable area, the perfection of the defense the finely dissected leaves afford against the sand blasts of a storm which lasted for nearly a week. Almost every other species in the area, which lay open to the direct action of the wind-driven sand was completely battered to pieces, while only about 15 per cent. of the Artemisias showed any sign of having been subject to a long continued action of a destructive force.

Upon the upper beach, also, is to be found in favored situations the beach pea, *Lathyrus maritimus*, although in no instance was it at all a dominant form. Upon the active dune is often to be found the frost grape,

*Vitis cordifolia.* Far more common, however, the common milk weed. *Asclepias Syriaca*, the bug-seed, *Corispermum hyssopifoliund* and *Puccoon*, *Lithospormum Gmelini.* This last is by far the most common of the groups, consisting in many instances a large proportion of the plants. A golden rod is not at all uncommon in such situations, but I am not certain what species it is. I am, however, confident it is not S. virgaurea gillmani, to which it is referred by Dr. Cowles in "The Ecological Relations of the Vegetation of the Sand Dunes of Lake Michigan." In no two cases are the conditions exactly similar, so that in spite of the paucity of species there is

At times the Artemisias are dominant plants over considerable areas.

no monotony. Different dominant species, differing proportions of those occurring make each area a special study. If we add to these the varying adaptations of the same species and the fact that at best any victory of the plants is but apparent, we can understand something of the complexity of the problem. The illustration on page 127 shows a large pine dying because of an uncovering of its roots during the storm mentioned above.

The succulent type of annuals was not so strongly marked as I had expected, but dissected leaves, the profile position, inrolling of leaf blades, and coverings of hairs seemed the dominant adaptations against the excessive transpiration and doubtless also against the fierce heat of the sun. Against the wind action the prostrate or trailing habit and great rigidity were the prevailing adaptations among herbaceous plants. Against sand coverings, nodal rooting and branching root stocks are almost universal among the

annuals. Where perennials have obtained a foothold, the long, thick tap-root is usually sufficient to give a new lease of life. Against the mechanical effects of the sand, the prostrate habit, the dissected leaves and at times

Any victory of the plants is but apparent. After years of possession of the soil they may be dislodged by the shifting of the soil under the action of the wind.

an extremely tough and resistant structure. The first two are by far the more common and apparently the more effective.

From the standpoint of the plant no situation can be more pitilessly cruel than the stretches of white, restlessly shifting sand making up the beaches and dunes. In a certain sense, no other situation furnishes ecologi-

cal problems of such apparent simplicity, but even here, as I have tried to show, the problem is really one of extreme complexity. If in any measure this paper serves to indicate how utterly without significance much so-called ecological study really is, and to stimulate to work along these lines that is really analytic, that recognizes the fact that no ecological problem is in reality simple and needs long-continued, oft-repeated observation and reflection before generalizations are made, it will have a distinct value quite apart from the specific subject discussed.

# Parasitic Plant Diseases Reported for Indiana.

Frank D. Kern.

The following summary of plant diseases in Indiana has been made up from information which has been accumulating during the past few years at the Botanical Laboratory of the Indiana Experiment Station.

In this list only the more important diseases have been considered from the standpoint of the cultivator. The information at hand is far from complete, since the diseases are invariably reported by common names, and as it is impossible to investigate or verify each case there is a probability that disturbances in growth and health do not always have the proper causes assigned. An effort has been made to classify the diseases according to their pathological effects, fifty-six in all being discussed. Such a grouping is difficult, owing to the lack of knowledge concerning the exact manner in which many of the parasites act.

Before taking up the detailed account it will be of interest from the point of view of the mycologist to consider the parasites which are held responsible for the various diseased conditions of root, stem, leaf and fruit. Out of fifty species under discussion forty-five are *fungi*, five *bacteria*, and one a *slime-mould*. Three species are causes for two separate diseases each, while three have no cause assigned, thus bringing the total up to fifty-six, the number selected for consideration by this paper. The fungus parasites are divided among thirty-two genera belonging to classes as follows: *Ascomycetes*, nine; *Basidiomycetes*, nine; *Phycomycetes*, one; *Fungi Imperfecti*, thirteen. Under the general term of *Fungi Imperfecti* are included a miscellaneous lot of forms whose life histories are imperfectly understood; some may have no other stages, while others may have connections not yet discovered. Comparatively recently three which were formerly classed here have had their perfect stages identified and have been transferred to the class *Ascomycetes*. These are the Bitter-rot fungus of the apple, the Scab-fungus of the apple and pear and the Brown-rot fungus of the peach and plum. The bacterial parasites are divided among two genera, both belonging to the same family, *Bacteriaceae*.

The enumeration of specific diseases is as follows:

I. Root diseases, affecting absorption of food materials—

Crown gall (cause uncertain). On fruit trees, small fruits, known to occur; extent of injury not reported.

Root-rot (Fungi not identified). On fruit trees; troublesome in orchards, principally in southern part.

Club-root (Myxomycetes, Plasmodiaphora Crassicae). On cabbages and other cruciferae. Distribution not known. Reported from market gardening regions about larger cities.

II. Stem diseases, affecting ascent of sap and transpiration—

Fire-blight (Bacillus amylovorous). On apples, pears and quinces in all parts of the State. Very destructive and difficult to control.

Black-knot (Plowrightia morbosa). On plums and cherries. Common all over State on plum trees. Cherries less injured by it.

Black-rust (Puccinia graminis). On wheat, chiefly, but attacking also other grains and grasses. Occurs everywhere. Extent of injury in any particular season usually dependent upon weather.

Black-rot (Pseudomonas compestris). On cabbage, cauliflower and related plants. Affects leaves also, and finally entire head. Very destructive in some localities.

III. Wood diseases, affecting absorption and transfer of water—

Wilt (Bacillus tracheiphilus). On melons and cucumbers. A common and injurious trouble affecting melons, especially in southern countries. Few reports concerning cucumbers; this crop of much less importance.

Blight (Bacillus salanacearum). On tomatoes. Few local reports of this. May be due to other causes than bacteria.

IV. Bark diseases, affecting transpiration chiefly—

Canker (Spaerapsis malorum, Bacillus amylovorus, Glomerella rufomaculaus). On apple trees. Cankers may be due to the parasites mentioned or others. Occurrence of any except the first mentioned has not been verified.

Asparagus rust (Puccinia asparagi). On asparagus. Bad locally in northwestern portion of State.

Authracuose (Gleosporium venetum). On blackberries and raspberries. Often very destructive.

V. Leaf diseases, affecting assimilation and transpiration—

Rusts, caused by uredineae (Gymnosporangium sup.). On apple, pear, quince and red cedar. Not reported as very destructive on cultivated apples; common on wild crabs or thorns.

(Puccinia rubigo-vera.) On wheat. This is the leaf rust and is usually common, but not especially injurious.

(Puccinia graminis.) On wheat and other cereals. This is the stem rust and only rarely occurs to any extent on the leaves.

(Puccinia caronata.) On oats. Occurs very commonly on leaves, but is not accountable for losses of any extent.

(Uromyces trifalii.) On clover. Not known to be of much economic importance, though quite common.

(Puccinia poarum.) On blue-grass, often in lawns.

(Puccinia sarghi.) On corn. Very widespread and common, but not especially injurious.

(Gymnoconia interstitialis.) On blackberry and raspberry, called the orange leaf rust. Has a perennial mycelium, but manifests itself only in the leaves. Common and distructive.

(Kuehneola albida.) On blackberry and raspberry. First noticed this season. Not of importance.

(Uromyces appendiculatus.) On beans. Extent and damage unknown.

(Uromyces caryaphyllacearum.) On carnations in greenhouses.

(Puccinia chrysanthemi.) On chrysanthemums in greenhouses.

Spots and Blights—

(Phylosticta spp.) On apple, often causing premature defatiation.

(Cylindrosporium padi.) On cherry and plum. Not uncommon.

(Septoria ribes.) On gooseberry and currant. Extent unknown; crop of minor importance.

(Septoria lycospersici.) On tomato. Very injurious in some localities.

(Cercospora beticola.) On beets. Two reports have been received.

(Atternariae brassicae nigressceus.) On muskmellons. This is known as the leaf blight and is very injurious in some localities.

(Calletobuchum Lagenarium.) On melons. Known as anthraenace, and while affecting leaves, usually attacks stems and catyledons of young plants. Reported by several horticulturists.

Powdery mildew (Spaerothaera moro-uvae). On gooseberry. Extent of damage unkown.

Powdery mildew (Podosphaera oxyacanthae). On cherry. Extent of damage unknown.

Leaf curl (Exoascus defarmaus). On peach. Usually quite prevalent.

Early blight (Alternaria solani). On potato. Usually prevalent, doing considerable damage.

Late blight (Phytophthora infestaus). On potato. Present to some extent; usually very destructive.

Black-rot (Pseudomonas compestrio). On cabbage and closely related crops.

VI. Fruit, Seed and Tuber diseases, affecting crop's economic value, directly—

Apple rots, ripe or bitter (Glomerella rufomaculaus); Apple rots, black (Sphaerapsis malorum). Usually common and causes of considerable losses.

Brown rot (Scleratinia fructigena). On peaches and plums chiefly, often causing a loss of half the crops.

Scab (Venturia inaequalis). On apple: very common and injurious. (Venturia pyrina). On pear; prevalent, but not especially prevalent. (Cladosperium carphyllum). On peach; bad on some varieties.

Black rot (Gnignardia bidwelli). On grape. Widespread and injurious.

Fruit rot (cause uncertain). On tomato. Very injurious in some localities.

Flyspeck and sooty blotch (Leptothyrum and Phyllachara spp.). On apple, often affecting a considerable per cent. of the crop.

Smuts (Ustilago leae). On corn; widespread, sometimes causing bad losses. (Ustilago avenae.) On oats; usually bad; losses underestimated. (Ustilago tritici.) On wheat; so-called loose smut; usually prevalent. (Tilletia foetaus.) On wheat; so-called stinking smut; usually prevalent.

Wheat scab (Fusarium culmorum). On wheat; usually more or less abundant; sometimes accountable for heavy losses.

White mold of corn (Fusarium sp.). Very abundant in some localities during present and past seasons.

Potato scab (Oospora scabies). Occurs quite generally over the State.

Brown rot of potato (Bacillus solanacearum). Often the cause of considerable losses in all parts of State.

Black rot of sweet potato (Ceratocystis finbriata). Distribution and extent of injury unreported.

Selerotinia fructigena (ascus stage) showing apothecia about mummied peach.

## Notes on the Occurrence of Sclerotinia Fructigena.

Frank D. Kern.

The rotting of the peach and plum fruit at the beginning of the ripening period is a rather familiar occurrence. Soft, brown spots appear, which usually grow until the whole fruit becomes rotten and finally shrivels up, becoming mummified. Twigs, leaves and flowers may also be attacked and exhibit discolored areas.

The rot is caused by a fungus, doubtless best known as *Monilia fructigene*, a name given it by Persoon[1] in 1801. That it was simply the conidial form of some ascomycetous species, was strongly suspected by several investigators and Schroeter[2] was even confident enough to transfer it to the genus Sclerotinia in 1893. This, however, remained a mere assumption until 1902, when Norton[3] collected the apothecia at several localities in Maryland, and established, by means of cultures, their relation to the conidial form.

Although the perfect stage had been diligently searched for before this was the first time it had ever been reported. Because this form has been so rarely seen, and because of the economic importance of the fungus in the other phase of its life history, it was with unusual delight and interest that the apothecia were discovered in the spring of 1906 in Indiana. Two collections were made, both at Lafayette, and by Prof. J. C. Arthur, on buried peaches, under trees in his garden, April 21; another by Dr. E. W. Olive and the writer, on buried plums, in a trash heap on a vacant lot, May 3. The earlier collection was in perfect condition, while the latter was somewhat dried. Both discharged clouds of spores when first disturbed, and when jarred even after partial drying made several subsequent discharges.

Only the mummied fruits which were buried or partially covered bore apothecia. On the plums one to three or four arose from a single fruit, while on the peaches as high as thirty or forty appeared about the sides of

[1] Persoon, Syn. Fung., 693, 1801.
[2] Schroeter, Krypt. Fl. Schles, 3[2]:67, 1893.
[3] J. B. S. Norton, Irons. Acad. Sci., Sb. Louis, 12:91-97, pls. 18-21, 1902.

one fruit. (Illustration.) The disks are light brown, at first companulate, becoming cup-shaped, averaging about one-half to three-fourths of a centimeter broad when full grown. The stipes are comparatively slender and usually about one to two centimeters long, where that is sufficient to bring the disks above the surface.

In every case there was reason to suppose that the fruits bearing the ascus stage were not from the crop of the immediate preceding season, but that they were one year older. In a recent conversation, Prof. Norton confirmed this opinion. Schellenberg[4] has found this to be true, also, of two other species of Sclerotinia in Europe. The length of the period required for the development of the apothecia is doubtless the factor which is responsible for their scarcity, since it affords so much time and opportunity for the mummied fruits to be destroyed or removed from the vicinity of the trees. The above collection in a trash heap shows that development takes place wherever the dried rotted fruits are covered by soil or humus a sufficient length of time, but in such a location it is only by accident that they would be discovered.

While the ascoporic form is so excedingly rare, the conidial form is just the opposite. As the cause of the *brown rot* of peaches and plums, it is the most common and destructive enemy of these crops.

In 1905 it was estimated that *brown rot* caused a loss of one-fourth of the peach crop in the southern counties of the State. In 1906 the rot has been reported from twenty-six counties representing all parts of the State. Estimates as to the amount of damage vary from 10 to 50 per cent. of the entire crop. In the northern half of the State the early varieties seemed to sustain almost double the loss of the later ones. This is an illustration of the rapidity with which the rot spreads when the weather conditions are favorable. The fungus is dependent for a start at the beginning of a season chiefly upon conidiospores produced upon the mummied fruits lying on the ground or hanging in the trees. Warm, moist weather in August, at the ripening time, caused such a production of conidiospores from these mummy fruits that the fungus spread and caused more notable effects at that time than later, when the weather conditions were less favorable.

Plums in all parts of the State have been attacked during the present season, and a loss amounting in many instances to 75 per cent. of the crop has been suffered.

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[4] H. C. Schellenberg, Ueber Scheratinia Mespili und S. Ariae, Centr. f. Bak. 17:188-202, pls. 1-4, 1906.

All of the facts thus far presented, which pertain to the life-history of the *brown rot* fungus and its methods of passing through unfavorable seasons, emphasize the importance of collecting and destroying the so-called mummied fruits as a means of control. If these infected fruits are allowed to remain hanging to the trees or upon the surface of the ground the conidial stage begins its destruction at once the following season, while if they are permitted to become buried beneath the trees, ascospores form the second season which are capable of producing in turn the conidial stage.

# Additions to Indiana Flora No. 3.

Chas. C. Deam.

(The determinations have been made by competent authorities, and specimens are deposited in my herbarium.)

***Paspalum Muhlenbergii*** **Nash.**

**Crawford County, July 11, 1899. In waste place near Wyandotte cave.**

***Panicum praecosius*** **Hitchcock No. 1270.**

**Steuben County, July 23, 1906. On top of dry wooded gravelly hill on east side of Hog-back Lake.**

***Festuca Shortii*** **Kunth.**

**Allen County, June 3, 1906; Brown County, May 23, 1906; Fountain County, June 4, 1905; Posey County, May 25, 1906.**

***Carex stricta angustata*** **(Boott.) Bailey.**

**Allen County, June 3, 1906. In slough along St. Joe river east of Robinson park.**

***Carex Haydeni*** **Dewey.**

**Fountain County, June 5, 1905.**

***Carex pedicillata*** **(Dewey) Britton.**

**Blackford County, April 29, 1906; Steuben County, May 28, 1905.**

***Carex rosea radiata*** **Dewey.**

**Allen County, June 3, 1906.**

***Carex interior*** **Bailey No. 980.**

**Porter County, June 16, 1900 (collected by L. M. Umbach); Wells County, June 1, 1906.**

***Carex canescens*** **L.**

**Fountain County, June 4, 1905.**

***Carex canescens disjuncta*** **Fern.**

**Steuben County, May 28, 1905.**

***Carex siccata*** **Dewey.**

**Steuben County, May 28, 1905.**

***Carex mirabilis*** **Dewey.**

**Fountain County, June 5, 1905.**

*Carex festucacea brevior* Fernald No. 1046.

Allen County, June 5, 1906.

*Carex Bicknellii* Britton.

Steuben County, June 16, 1903.

*Batrachium longirostris* (Godr.) F. Schultz.

Allen County, June 3, 1906; Wells County, June 13, 1899. No doubt most of the plants named trichophyllum (Chaix.) Bosch. should be referred to this species.

*Fragaria Virginiana Grayana* (Vilm.) Rydb.

Blackford County, June 22, 1905; Franklin County, May 13, 1906; Marion County, April 30, 1905; Wells County, June 16, 1901.

*Viola conspersa* Reich.

Wells County, May 11, 1906; Steuben County, May 13, 1906. It is quite probable that what has been passing as Viola Labradonica Shrank should be referred to this species.

*Viola pallens* (Banks) Brainard.

Blackford County, April 29, 1906; Wells County, June 1, 1906. *Viola blanda* Willd. is often associated with this species and possibly mistaken for it.

*Rhamnus alnifolia* L'Her.

Steuben County, August 1, 1903.

*Campanula uliginosa* Rydberg.

Noble County, July 21, 1904; Steuben County, August 11, 1903; Wells County, July 6, 1902. All specimens of *Campanula aparinoides* Pursh I have examined should be referred to this species, although *aparinoides* Pursh may occur in Indiana also.

*Lactuca Saligna* L. No. 1389.

Blackford County, August 3, 1906. This species was taken just south of Hartford, along interurban right of way.

*Bidens comosa* (A. Gray) Wiegand.

Blackford County, September 3, 1905; Wells County, September 21, 1902.

# The Lummi Indians.

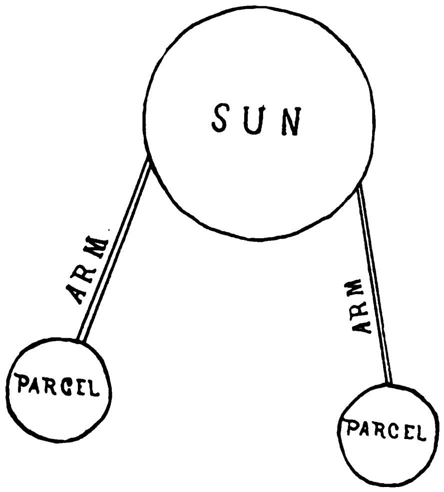
Albert B. Reagan.

The Lummi Indians occupy the Lummi Peninsula just across Bellingham Bay west from the City of Bellingham, Washington. The peninsula, containing about two townships, is their reservation. They number in all about three hundred and seventy-five, most of whom are half-breeds. These resemble the mulattoes of the south very much as to physical appearance and color; their hair, of course, is black and straight. The full-breeds are nearly all old Indians, most of whom are blind. They are all fishing Indians by nature. Formerly they lived almost wholly by fishing for salmon and trout; but since they took their allotments some years ago they live on their farms and till the ground most of the year, fishing only in August and September. At this time they sell fish to the canneries and also dry it for their own use. In old times they made flour from the fern root, but now the white-man's flour has taken its place. Their farming is very well done and their houses are often better than those of their white neighbors, though usually not kept so neat inside. The tribe as known to-day is made up of Nooksack, Lummi, Snowhommish and British Columbia Indians. They belong to the Salish linguistic stock, and now all talk the Lummi branch of that language. When that fails they use the Chenook jargon as a means of communication. The young people all speak English. They are advanced in civilization almost to our standard; many of them even take daily newspapers.

In old times these Indians practiced all the ceremonies known to their linguistic group. They waged war for the sole purpose of capturing slaves. They flattened their babies' foreheads so that a modern hat fits them better cross-wise than the way we wear it. They had mortuary dance ceremonies. They believed in the superhuman power of medicine men. They slashed themselves with knives and thrust their arms through with arrows and elk bones in the medicine ceremonies. They had give-away dance feasts at which the man who gave away most was made chief. And they carved or painted their special dreams or visions (called in Chenook "tomanawis") in conspicuous places in their "plank" houses, usually on totem poles, as a

mark of good luck or a guide to their lives. A carving of this sort is now to be found on each of the totem-posts of an old give-away, feast dance hall ("potlatch" house), now in ruins at the Portage on the reservation. An interpretation of this totem-tomanawis was given me as follows by Mr. McClusky (Indian), who also made me the copy of it given here:

"Chief Cha-we-tsot once owned the 'potlatch' house at the Portage. The drawings on the totem-posts are his 'tomanawis.' The sun, carrying a parcel of valuables in each hand, came to him in a dream and said: 'Your




To-ma-na-wis of Chief Cha-me-tsot.

storehouses (or trunks) will always be full. You will therefore give two more feasts than the average chief; custom had established the rule that the ordinary chief should give three feasts in a lifetime. So Chief Cha-we-tsot built the 'potlatch' house and carved his 'tomanawis' on its totem-posts. He then gave five feasts, two more than the average, as the sun in the vision had commanded him."

These Indians are now Catholics and all attend church every Sunday. When the priest is present he gives his sermon first in English and then in Chenook. When the priest is not present, the Indians pass around within the church from left to right, while they sing and pray a few minutes in

Indian before each of the passion pictures, the altar, and the image of Christ and of the Virgin Mary. Then the quietly leave the church, and, after eating their picnic dinner, go to the Sunday ball game.

Their government school was abandoned this year and their reservation will propably be thrown open this winter.

## The Mammalian Remains of the Donaldson Cave.

Walter L. Hahn.

While occupying the Donaldson Farm Fellowship in Zoology in Indiana University, the writer has had occasion to make frequent trips into the Donaldson Cave, situated about three miles southeast of Mitchell, Indiana. On one of these trips bones of small mammals were noticed and diligent collecting on that and subsequent occasions has resulted in the finding of identifiable remains of 244 individuals, representing eleven species. The occurrence and relative abundance of some of these species is of considerable interest and this occasion is taken to place all on record.

The list follows

1. *Didelphis virginiana* Kerr. Opossum.
   A portion of one skull found on a gravel deposit in a side passage leading off from the "big room" of the cave.
2. *Odocoileus virginianus* (Boddaert). Virginia deer.
   A vertebra found not far from the preceding specimen has been identified for me by Mr. J. M. Gidley, Vertebrate Paleontologist of the National Museum, as the fourth cervical of this species. It was doubtless carried in, either by a flood or by some carniverous animal, in the days when deer were plentiful in Indiana, and since that time has lain undisturbed in the darkness of the cave.
3. *Sylvilagus floridanus* (Allen). Rabbit.
   Remains of three individuals found.
4. *Peromyscus leucopus* (Rafinesque). White-footed mouse.
   Mandibles of four individuals found.
5. *Microtus pinetorum* (Le Conte). Pine mouse.
   Four of this species also.
6. *Blarina brevicauda* (Say). Large shrew.
   One skull.

7. *Pipistrellus subflavus* (F. Cuvier). Georgian bat.

Partial skulls and mandibles representing eight individuals of this species were found at various points in or near the "big room."

8. *Lasiurus cinereus* (Beauvois). Hoary bat.

This species is widely distributed, but everywhere rare. The finding of two partial skulls and skeletons adds this locality to the two previously recorded for Indiana.

9. *Lasiurus borealis* (Müller). Red bat.

Remains of this species were far more abundant than of any other. More or less complete skulls and skeletons of 203 individuals were found. The abundance of the species will be discussed later.

10. *Myotis subulatus* (Say). Say bat.

One skull can be unquestionably referred to this species.

11. *Myotis lucifugus* (Le Conte). Little brown bat.

Nine skulls could be positively referred to this species. Eight others were probably *M. lucifugus*, but were too badly broken to determine with certainty whether they belonged to this or to the last preceding species.

It will be noted that the above list contains a large number (203) of specimens of the red bat and but few (17) of the little brown bat. If we turn to the living representatives of the two species this abundance is exactly reversed. Mr. W. S. Blatchley informs me that the proportion of the two species in Wyandotte Cave is about 1 to 1,000, the larger number being the brown. Mr. A. M. Banta, who has had a very extensive acquaintance with the cave fauna of Monroe and Lawrence counties, is of the opinion that the red bat never enters caves at all. and that, though common above ground, it is less abundant than the brown species. My own observations are in complete accord with those of Mr. Banta.

The period at which this change in relative abundance has taken place can not be determined accurately from the evidence now at hand. Evidently it has been within recent geological times, since many of the bones were found in places where they would have been destroyed by changes which must have taken place during some recent epoch. On the other hand many of them were found partially covered with fragments of stone which have gradually weathered away from the larger masses, and this would seem to indicate that at least a part of the bones are many years, possibly

centuries, old. For the most part they seem to lie where they fell when the animals dropped dead from the places where they clung to the roof of the cave. This seems to indicate that they died, one at a time, from natural causes.

The above facts seem to warrant two conclusions: (1) The red bat is less abundant than formerly; (2) it has changed its habits and no longer frequents caves as it did formerly.

# Some Notes on Indiana Birds.

Amos W. Butler.

*Nyctea nyctea* (Snowy Owl).—One reported by Louis A. Test, upon authority of J. Keegan, as having been taken near Washington, Daviess County, Indiana, November 5, 1904.

I saw one in Deschler's cigar store, Lahr House, Lafayette, which was procured by Geo. M. Timberlake from a man who shot it about fifteen miles south of Lafayette in the winter of 1901-02. Beasley and Parr, taxidermists, Lebanon, report that they mounted this specimen in November or early in December of 1901. Snowy Owls have been more generally distributed over the State the present winter and more individuals have been reported than ever before since records have been kept.

November 25, 1905, while at Hammond, Lake County, Mr. LeGrand T. Meyer told me that two fine specimens of this bird had been taken near that place a few days before. One of these we saw afterwards in the possession of Mr. Schmid, who mounted it and who also had the other one at the same time in his work room. Mr. Meyer has kindly supplied me with the following data of these, and three other birds of the same species taken in that vicinity:

First.—A man by the name of Johnson killed one on November 12, 1905, about a mile and a half southeast of Tolleston, Indiana, in the gravel pits.

Second.—Fred Burg shot one on the lake front of Lake Michigan, near Indiana Harbor, on November 19, 1905, which is now in the possession of Mr. Louis Freeze of Hammond.

Third.—Wm. J. Thompson killed one near Wolf Lake ice houses in Hammond, on November 25, 1905. This one was on the top of a telegraph pole when killed.

Fourth.—One was killed on Wolf Lake, near Lake Michigan, in Hammond, by a person unknown to me, which is now in the possession of Louis Mankowski of this city, which was killed November 23, 1905.

Fifth.—At the time it was killed there was another one with it which the hunter was unable to secure.

The specimens Mr. Schmid had were numbers one and four, given above.

Beasley and Parr, Lebanon, Indiana, have mounted quite a number of these birds recently. From information kindly supplied by them regarding specimens in their hands I have been able, through extended correspondence, to collect some interesting facts regarding this dispersion of these owls over Indiana this winter. They have been reported from the following counties: Allen, Benton, Fountain, Hancock, Johnson, Lake, Marion, Miami, Montgomery, Noble, Shelby, Sullivan, Warren.

H. A. Dinius of Fort Wayne reports that two Snowy Owls were observed on the Godfrey, Indiana, Reservation, west of that city, December 22, 1905.

One was shot by Clem Woodhams in Bolivar township, Benton County, November 10, 1905. The same gentleman informs me that one was seen north of Otterbein in that county about December 24, 1905.

One of two owls seen was shot nine miles east of Fowler, in Benton County, November 4, 1905, by a corn husker working for Thomas Eastburn. It was wounded and brought alive to Fowler. The second one was taken afterwards. They are reported to be male and female. They were sent by J. F. Warner of Fowler to be mounted, who reports on January 4, 1906, another one observed some days before at Earl Park.

J. W. Crouch of Fowler has a Snowy Owl that was killed by Nelson Hendricks five miles west of that place about February 12, 1906.

J. R. Opp has a specimen taken four miles west of Otterbein December 21, 1905. Another was shot near there on December 4, 1905.

One shot November 29, 1905, two miles southeast of Mellott, in Fountain County, by John Whalen, just after dusk, after it had killed two old hens. Mounted for Red Men's Hall at Mellott.

One shot one mile northwest of Fortville, Hancock County, by Ottis Shepherd. Reported by David Fair of Fortville.

John Hammer took a Snowy Owl about six miles south of Franklin, Johnson County. It is now owned by S. B. Eccles.

Gus Habich, Indianapolis, received two of these owls recently. Both were killed about December 1, 1905. One was shot by William Stroble, near Shelby, Lake County; the other by Frank Hoffman, below Shelbyville, in Shelby County, Indiana.

One killed by Isom Kelsey, two and one-half miles southwest of Shelbyville, November 30, 1905.

One killed by John Tucker, four miles north of Fairland, Shelby County, about November 16, 1905. Owned by D. H. Tucker.

One owned by Fletcher M. Noe, Indianapolis, he informs me was taken near Southport, Marion County, Indiana, December 20, 1905. He reports that six or seven have been brought in to him the present fall and winter.

One, a male, killed by Frank Clark, in Erie Township, Miami County, December 17, 1905. The next day a female was killed in that vicinity by Rawley Runnell. The first one was mounted for the First National Bank of Peru. Reported by Joseph H. Shirk.

One shot three miles northwest of Linden, Montgomery County, by George Ciderdin, November 22, 1905. Owned by J. M. Hose of Linden.

One killed near Darlington, Montgomery County, November 21, 1905, by N. Royer. Reported by S. G. Kersey.

One reported by Henry A. Link to have been killed near Avilla, Noble County, Indiana, a few days prior to December 14, 1905.

W. S. Blatchley, State Geologist, has a photograph, taken the past fall, of a bird of this species, in the possession of J. W. Sampson, Farmersburg, Sullivan County, Indiana. Mr. Sampson writes that another was killed at Blackhawk, about six miles east of Farmersburg, about the same time.

John Morgan killed one in Warren County, December 21, 1905.

A fine specimen, seen in the window of the Starr Piano Co., Richmond, Indiana, was killed by Mr. Edgar Moon, near Bowersville, Greene County, Ohio, November 8, 1905. Reported by J. E. Perkins.

Mr. Louis A. Test of Lafayette reports, upon the authority of Mr. L. J. Owens of that city, the capture of one by Mr. Carl Townsley at Chalmers, Indiana, about November 25, 1906.

Mr. Joseph F. Honecker reports seeing six of these owls near Oak Forest, Franklin County, December 15, 1905.

Mr. J. W. Crouch informs me that a Snowy Owl, almost perfectly white, was killed November 11 or 12, 1906, at Fowler, Benton County, and brought to him. This is interesting as giving an early record for this year from the same county where a number were found in 1905.

*Elanoides forficatus* (Linn.) Swallow-tailed Kite.—On September 3, 1906, one was seen one mile south of Brookville, Ind.—(Jos. F. Honecker.)

*Falco peregrinus anatum* (Bonap.) Duck Hawk.—A pair were found nesting in an old stone quarry near Laurel, Ind., April 28, 1906. The two eggs were placed in a small cavity on the bare rock on a shelf ten or

[illegible] them were bones and feathers of [illegible]. The eggs are now in the collection of Jos. F. [illegible] they were found and reported.

[illegible] Pigeon: Wild Pigeon.—Joseph F. [illegible] a Wild Pigeon with young, near Haymond, in [illegible] of 1885. The same person says: "On May [illegible] good fortune to find three nests of the Wild Pigeon [illegible] of Oak Forest, Franklin County, Indiana. The [illegible] to fifteen feet from the ground in a small elm tree. [illegible] two eggs each and one contained two young only a few days old. I saw the six adult birds at one time, and observed them until the young were grown. They were last seen together in a flock, July [illegible]. There is another record of the capture of a specimen in Shelby County.

*Meleagris gallopavo.* (Linn.) Wild Turkey.—According to Mr. E. J. Chandler, a few are still to be found in the southern part of Knox County, Ind.

*Dendroica vigorsii.* Pine Warbler.—C. P. Smith, during the summer of 1904, visited the sand dunes near Michigan City. There among the pine trees he found Pine Warblers. They were fairly common June 19-23. Though the birds were in full song, he did not find the nest. He describes the song as very similar to that of a Chipping Sparrow; in fact, so similar that he was deceived by it at first. The preceding summer (1903) the same observer, while studying the biology of the State Forest Reserve, at Henryville, saw Pine Warblers three or four times among the pine-covered "knobs." The last of July he found adults feeding young that were practically full grown. They doubtless nested there.

*Pelidna alpina pacifica.* Red-backed Sandpiper; American Dunlin.—A specimen taken October 11, 1905, from a flock of shore birds at a pond in Marion County, north of Indianapolis, was presented to me by Philip Baker. This is the first fall record for this vicinity.

*Aegialitis meloda circumcincta.* Belted Piping Plover.—A fine group of these birds with four eggs, in the collection of the Chicago Academy of Sciences was taken at Millers, Indiana, June 13, 1905 (F. M. Woodruff).

*Numenius borealis.* Eskimo Curlew.—There are few recorded specimens of this rare migrant from Indiana. It, therefore, is of interest to note from Mr. J. H. Fleming, Toronto, Ont., that he has one marked Chalmers, Ind., male, April 19, 1890(?).

*Phalacrocorax dilophus.* Double-crested Cormorant.—Mr. Roman

Eichstodt of Michigan City has a specimen taken by him inside the breakwater there, the last of November, 1903. No others of this species were seen.

*Sula bassana.* Gannet.—A few months ago I was taken to see a bird of this species in the store of Roman Eichstodt, Michigan City, Ind. It

twelve feet from the ground. About them were bones and feathers of pigeons, chickens and ducks. The eggs are now in the collection of Jos. F. Honecker, Oak Forest, Ind., by whom they were found and reported.

*Ectopistes migratorius.* Passenger Pigeon; Wild Pigeon.—Joseph F. Honecker reports seeing a Wild Pigeon, with young, near Haymond, in Franklin County, in the spring of 1905. The same person says: "On May 18, 1906. I had the good fortune to find three nests of the Wild Pigeon about one half mile east of Oak Forest, Franklin County, Indiana. The nests were about eight to fifteen feet from the ground in a small elm tree. Two of them contained two eggs each and one contained two young only a few days old. I saw the six adult birds at one time, and observed them until the young were grown. They were last seen together in a flock, July 13. There is another record of the capture of a specimen in Shelby County.

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*Sula bassana.* Gannet.—A few months ago I was taken to see a bird of this species in the store of Roman Eichstodt, Michigan City, Ind. It

was in immature fall plumage, as determined by the U. S. Biological Survey, to which a photograph was sent. The bird was killed, according to the owner, on Lake Michigan, in November, 1904, about two miles from Michigan City. It was said to be unlike anything before seen in that vicinity.

*Oceanodroma castro.* (*Oceanodroma cryptoleucura* Ridgw.) Hawaiian Petrel.—A specimen of this rare species, whose distribution seems to be almost world wide, was given to me by Alden M. Hadley of Monrovia, Ind. He obtained it from Mr. N. H. Gano, who, on June 15, 1902, found it fluttering in a wheelbarrow in his yard at Martinsville, Ind. He picked up the bird, but it soon died. Its stomach was entirely empty and it had evidently died of hunger and exhaustion. The bird was sent to Mr. Hadley, who preserved the skin. It was recognized as a petrel, and the species was kindly determined by Dr. C. W. Richmond of the Smithsonian Institution. Five specimens of this bird, from its collection, were later sent me for examination. The following notes and measurements in inches are given:

| Cat. No. | Sex. | Locality. | Date. | Collector. | Wing. | Tail. | Tarsus. | Tail. |
|---|---|---|---|---|---|---|---|---|
| 132764 | ♂ | Galapagos...... | April 4, 1891 | C. H. Townsend. | 6.125 | 3.250 | .937 | Slightly forked. |
| 189861 | ♀ | Maderia......... | Sept. 12, 1902 | ............... | 5.750 | 3.000 | .937 | Much worn. |
| 189860 | ..... | Maderia......... | Oct. 14, 1902 | ............... | 6.500 | 3.555 | .937 | Very slightly forked. |
| 115461 | ..... | Kauwai, H. I.... | ............ | Knudsen....... | 5.750 | 3.968 | .937 | Nearly square. |
| 154436 | ♀ | Wash., D. C..... | Aug. 29, 1893 | W. Palmer..... | 6.250 | 3.125 | .937 | Nearly square. |
| ..... | ..... | Martinsville, Ind. | June 15, 1902 | N. H. Gano.... | 6.000 | 3.500 | .937 | |

# Blood Pressure in Man.

G. E. Hoffman.

(Abstract.)

The paper consists of a tabulation of the readings of blood pressure in 220 men with age, day and hour of day, mental condition, and the condition of arteries, heart and kidneys; with conclusions as to what factors influence and are influenced by the blood pressure in man.

As the subjects were unfamiliar with the procedure it itself increased the blood pressure in most cases so that the readings are high for them. The highest, taking the systolic as most reliable, was 270 in an old man with beady arteries: the lowest, 88; thirteen were above 200; six were below 100; the averages for the series was 134 mmg Hg by the Rivi-Rocci mercurial sphygmomanometer, Stanton's form.

Age, by the changes in the blood vessels, is the most constant factor in change of blood pressure, which increases with age; the condition of the arteries is a determining factor; the more rigid their walls the higher the blood pressure; all with high pressure have rigid arteries; coincidently, casts and albumen occurred in the urine, indicative of lesion in the kidneys. Valvular lesion of the heart lessening its efficiency raises the systolic pressure.

In stupor invariably the blood pressure was low, as in the cases of catalepsy, which gave the low records; likewise in dementia the blood pressure is relatively low; also in maniacal conditions it is decreased, approaching its normal with recovery; and contrawise the blood pressure is raised in melancholia and in states marked with delusions of persecution; in general paresis it varies according to the mental condition. This correspondence of mental condition to blood pressure is tolerably uniform.

# INDEX.

# PROCEEDINGS

OF THE

# Indiana Academy of Science

## 1907

EDITOR, . . . . . . . . . . . LYNN B. McMULLEN

INDIANAPOLIS, IND.
1908

INDIANAPOLIS
WM. B. BURFORD, PRINTER
1908

THE STATE OF INDIANA,
EXECUTIVE DEPARTMENT,
March 24, 1908.

**Received by the Governor, examined and referred to the Auditor of State for verification of the financial statement.**

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OFFICE OF AUDITOR OF STATE,
INDIANAPOLIS, April 17, 1908.

**The within report, so far as the same relates to moneys drawn from the State Treasury, has been examined and found correct.**

J. C. BILLHEIMER,
*Auditor of State.*

---

APRIL 17, 1908.

**Returned by the Auditor of State, with above certificate, and transmitted to Secretary of State for publication, upon the order of the Board of Commissioners of Public Printing and Binding.**

FRED L. GEMMER,
*Secretary to the Governor.*

---

**Filed in the office of the Secretary of State of the State of Indiana, April 17, 1908.**

FRED A. SIMS,
*Secretary of State.*

---

**Received the within report and delivered to the printer April 17, 1908.**

HARRY SLOUGH,
*Clerk Printing Bureau.*

## TABLE OF CONTENTS.

## AN ACT TO PROVIDE FOR THE PUBLICATION OF THE REPORTS AND PAPERS OF THE INDIANA ACADEMY OF SCIENCE.

[Approved March 11, 1895.]

**Preamble.**

WHEREAS, The Indiana Academy of Science, a chartered scientific association, has embodied in its constitution a provision that it will, upon the request of the Governor, or of the several departments of the State government, through the Governor, and through its council as an advisory body, assist in the direction and execution of any investigation within its province, without pecuniary gain to the Academy, provided only that the necessary expenses of such investigation are borne by the State; and,

WHEREAS, The reports of the meetings of said Academy, with the several papers read before it, have very great educational, industrial and economic value, and should be preserved in permanent form; and

WHEREAS, The Constitution of the State makes it the duty of the General Assembly to encourage by all suitable means intellectual, scientific and agricultural improvement; therefore,

**Publication of the Reports of the Indiana Academy of Science.**

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana,* That hereafter the annual reports of the meetings of the Indiana Academy of Science, beginning with the report for the year 1894, including all papers of scientific or economic value, presented at such meetings, after they shall have been edited and prepared for publication as hereinafter provided, shall be published by and under the direction of the Commissioners of Public Printing and Binding.

**Editing Reports.**

SEC. 2. Said reports shall be edited and prepared for publication without expense to the State, by a corps of editors to be selected and appointed by the Indiana Acadmey of Science, who shall not, by reason of such services, have any claim against the State for compensation. The form, style of binding, paper, typography and manner and extent of illustration of such reports, shall be determined by the editors, subject to the approval of the Commissioners of Public Printing and Stationery. Not less than 1,500 nor more than 3,000 copies of each of said

**Number of printed Reports.**

reports shall be published, the size of the edition within said limits to be determined by the concurrent action of the editors and the Commissioners of Public Printing and Stationery: *Provided*, That not to exceed six hundred dollars ($600) shall be expended for such publication in any one year, and not to extend beyond 1896: *Provided*, That no sums shall be deemed to be appropriated for the year 1894.

Proviso.

Disposition of Reports.

SEC. 3. All except three hundred copies of each volume of said reports shall be placed in the custody of the State Librarian, who shall furnish one copy thereof to each public library in the State, one copy to each university, college or normal school in the State, one copy to each high school in the State having a library, which shall make application therefor, and one copy to such other institutions, societies or persons as may be designated by the Academy through its editors or its council. The remaining three hundred copies shall be turned over to the Academy to be disposed of as it may determine. In order to provide for the preservation of the same it shall be the duty of the Custodian of the State House to provide and place at the disposal of the Academy one of the unoccupied rooms of the State House, to be designated as the office of the Indiana Academy of Science, wherein said copies of said reports belonging to the Academy, together with the original manuscripts, drawings, etc., thereof can be safely kept, and he shall also equip the same with the necessary shelving and furniture.

Emergency.

SEC. 4. An emergency is hereby declared to exist for the immediate taking effect of this act, and it shall therefore take effect and be in force from and after its passage.

## AN ACT FOR THE PROTECTION OF BIRDS, THEIR NESTS AND EGGS.

SECTION 602. It shall be unlawful for any person to kill, trap or possess any wild bird, or to purchase or offer the same for sale, or to destroy the nests or the eggs of any wild bird except as otherwise provided in this section. But this section shall not apply to the following named game birds: The Anatidæ, commonly called swans, geese, brant, river and sea duck; the Rallidæ, commonly known as rails, coots, mudhens, and gallinules; the Limicolæ, commonly known as shore birds plovers, surf birds, snipe, woodcock, sandpipers, tatlers and curlews; nor to English or European house sparrows, crows, hawks, or other birds of prey. Nor shall this section apply to any person taking birds or their nests or eggs for scientific purposes under permit, as provided in the next section. Any person violating the provisions of this section shall, upon conviction, be fined not less than ten dollars nor more than fifty dollars. Birds.

SEC. 603. Permits may be granted by the Commissioner of Fisheries and Game to any properly accredited person, permitting the holder thereof to collect birds, their nests or eggs for strictly scientific purposes. In order to obtain such permit the applicant for the same must present to said Commissioner written testimonials from two well-known scientific men certifying to the good character and fitness of said applicant to be entrusted with such privilege, and pay to said Board one dollar therefor, and file with him a properly executed bond in the sum of two hundred dollars, payable to the State of Indiana, conditioned that he will obey the terms of such permit, and signed by at least two responsible citizens of the State as sureties. The bond may be forfeited and the permit revoked upon proof to the satisfaction of such Commissioner that the holder of such permit has killed any bird or taken the nests or eggs of any bird for any other purpose than that named in this section.

# Indiana Academy of Science.

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J. W. BEEDE, J. H. RANSOM.

EDITOR,
LYNN B. MCMULLEN, Indianapolis, Ind.

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| 1901-1902 | Harvey W. Wiley | John S. Wright | Donaldson Bodine | Geo. W. Benton | J. T. Scovell. |
| 1902-1903 | W. S. Blatchley | John S. Wright | Donaldson Bodine | G. A. Abbott | W. A. McBeth. |
| 1903-1904 | C. L. Mees | John S. Wright | J. H. Ransom | G. A. Abbott | W. A. McBeth. |
| 1904-1905 | John S. Wright | Lynn B. McMullen | J. H. Ransom | G. A. Abbott | W. A. McBeth. |
| 1905-1906 | Robert Hessler | Lynn B. McMullen | J. H. Ransom | Charles R. Clark | W. A. McBeth. |
| 1906-1907 | D. M. Mottier | Lynn B. McMullen | J. H. Ransom | G. A. Abbott | W. A. McBeth |
| 1907-1908 | Glenn Culbertson | J. H. Ransom | A. J. Bigney | G. A. Abbott | W. A. McBeth. |

# CONSTITUTION.

## ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SEC. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science, to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other resources and riches of the State; to arrange and prepare for publication such reports of investigation and discussions as may further the aims and objects of the Academy as set forth in these articles.

Whereas, The State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or of one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

## ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident members or active members.

SEC. 2. Any person engaged in any department of scientific work, or in original research in any department of science, shall be eligible to active membership. Active members may be annual or life members. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars, and thereafter an annual fee of one dollar. Any person who shall at one time contribute

fifty dollars to the funds of this Academy may be elected a life member of the Academy, free of assessment. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Applications for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

SEC. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

## ARTICLE III.

SECTION 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a President, Vice-President, Secretary, Assistant Secretary, Press Secretary and Treasurer, who shall perform the duties usually pertaining to their respective offices, and in addition, with the ex-Presidents of the Academy, shall constitute an Executive Committee. The President shall, at each annual meeting, appoint two members to be a committee, which shall prepare the programs and have charge of the arrangements for all meetings for one year.

SEC. 2. The annual meeting of this Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the Executive Committee. There shall also be a summer meeting at such time and place as may be decided upon by the Executive Committee. Other meetings may be called at the discretion of the Executive Committee. The past Presidents, together with the officers and Executive Committee, shall constitute the council of the Academy, and repre-

sent it in the transaction of any necessary business not especially provided for in this constitution, in the interim between general meetings.

SEC. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing No question of amendment shall be decided on the day of its presentation.

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## BY-LAWS.

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1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The President shall deliver a public address on the morning of one of the days of the meeting at the expiration of his term of office.

3. The Press Secretary shall attend to the securing of proper newspaper reports of the meetings and assist the Secretary.

4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the President and countersigned by the Secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of business.

# MEMBERS.

## *FELLOWS.*

| | | |
|---|---|---|
| R. J. Aley | *1898 | Bloomington |
| J. C. Arthur | 1893 | Lafayette. |
| J. W. Beede | 1906 | Bloomington. |
| George W. Benton | 1896 | Indianapolis. |
| A. J. Bigney | 1897 | Moore's Hill. |
| Katherine Golden Bitting | 1895 | Lafayette. |
| W. S. Blatchley | 1893 | Indianapolis. |
| Donaldson Bodine | 1899 | Crawfordsville. |
| H. L. Bruner | 1899 | Irvington. |
| Severance Burrage | 1898 | Lafayette. |
| A. W. Butler | 1893 | Indianapolis |
| W. A. Cogshall | 1906 | Bloomington. |
| Mel. T. Cook | 1902 | Newark, Del. |
| John M. Coulter | 1893 | Chicago, Ill. |
| Stanley Coulter | 1893 | Lafayette. |
| Glenn Culbertson | 1899 | Hanover. |
| E. R. Cumings | 1906 | Bloomington. |
| D. W. Dennis | 1895 | Richmond. |
| C. R. Dryer | 1897 | Terre Haute. |
| C. H. Eigenmann | 1893 | Bloomington. |
| Percy Norton Evans | 1901 | West Lafayette |
| A. L. Foley | 1897 | Bloomington. |
| M. J. Golden | 1899 | Lafayette. |
| W. F. M. Goss | 1893 | Urbana, Ill. |
| Thomas Gray | 1893 | Terre Haute. |
| A. S. Hathaway | 1895 | Terre Haute. |
| W. K. Hatt | 1902 | Lafayette. |
| Robert Hessler | 1899 | Logansport. |
| H. A. Huston | 1893 | Chicago, Ill. |
| Edwin S. Johonnatt | 1904 | Terre Haute. |
| Robert E. Lyons | 1896 | Bloomington. |
| W. A. McBeth | 1904 | Terre Haute. |

*Date of election.

| | | |
|---|---|---|
| V. F. Marsters | *1893 | Bloomington. |
| C. L. Mees | 1894 | Terre Haute. |
| J. A. Miller | 1904 | Swarthmore, Pa. |
| W. J. Moenkhaus | 1901 | Bloomington. |
| D. M. Mottier | 1893 | Bloomington. |
| J. P. Naylor | 1903 | Greencastle. |
| W. A. Noyes | 1893 | Champaign, Ill. |
| Rolla R. Ramsey | 1906 | Bloomington. |
| J. H. Ransom | 1902 | Lafayette. |
| L. J. Rettger | 1896 | Terre Haute. |
| David Rothrock | 1906 | Bloomington. |
| J. T. Scovell | 1894 | Terre Haute. |
| Alex Smith | 1893 | Chicago, Ill. |
| W. E. Stone | 1893 | Lafayette. |
| Joseph Swain | 1898 | Swarthmore, Pa |
| M. B. Thomas | 1893 | Crawfordsville. |
| C. A. Waldo | 1893 | Lafayette. |
| F. M. Webster | 1894 | Washington, D. C. |
| Jacob Westlund | 1904 | Lafayette. |
| H. W. Wiley | 1895 | Washington, D. C |
| John S. Wright | 1894 | Indianapolis. |

* Date of election.

## NON-RESIDENT MEMBERS.

| | |
|---|---|
| George H. Ashley | Charleston, S. C. |
| J. C. Branner | Stanford University, Cal |
| M. A. Brannon | Grand Forks, N. D. |
| D. H. Campbell | Stanford University, Cal. |
| A. Wilmer Duff | Worcester, Mass |
| B. W. Everman | Washington, D. C. |
| Charles H. Gilbert | Stanford University, Cal. |
| C. W. Green | Columbia, Mo. |
| C. W. Hargitt | Syracuse, N. Y |
| O. P. Hay | New York City. |
| Edward Hughes | Stockton, Cal |
| O. P. Jenkins | Stanford University, Cal. |
| D. S. Jordan | Stanford University, Cal. |

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|---|---|
| J. S. Kingsley | Tufts College, Mass. |
| D. T. MacDougal | Bronx Park, New York City |
| T. C. Mendenhall | Worcester, Mass. |
| Alfred Springer | Cincinnati, Ohio. |
| Robert B. Warder | Washington, D. C. |
| Ernest Walker | Clemson College, S. C. |

## *ACTIVE MEMBERS.*

| | |
|---|---|
| George Abbott | Indianapolis. |
| Walter D. Baker | Indianapolis. |
| Edward Hugh Bangs | Indianapolis. |
| Lee. F. Bennett | Valparaiso. |
| Harry Eldridge Bishop | Indianapolis. |
| Lester Black | |
| William N. Blanchard | Greencastle. |
| Charles S. Bond | Richmond. |
| H. C. Brandon | Bloomington. |
| Fred J. Breeze | Remington. |
| E. M. Bruce | Terre Haute. |
| Lewis Clinton Carson | Detroit, Mich. |
| Herman S. Chamberlain | Indianapolis. |
| E. J. Chansler | Bicknell. |
| Otto O. Clayton | Geneva. |
| Howard W. Clark | Chicago, Ill. |
| H. M. Clem | Monroeville. |
| Charles Clickener | Silverwood, R. D. No. 1. |
| Charles A. Coffey | Petersburg. |
| Ulysses O. Cox | Terre Haute. |
| William Clifford Cox | Columbus. |
| J. A. Cragwall | Crawfordsville. |
| M. E. Crowell | Franklin. |
| Lorenzo E. Daniels | Laporte. |
| S. C. Davisson | Bloomington. |
| Charles C. Deam | Bluffton. |
| Martha Doan | Westfield. |
| J. P. Dolan | Syracuse. |

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| **Herman B. Dorner** | Crawfordsville. |
| **Hans Duden** | Indianapolis. |
| **Arthur E. Dunn** | Logansport. |
| **Herbert A. Dunn** | Logansport. |
| **M. L. Durbin** | Anderson. |
| **J. B. Dutcher** | Bloomington. |
| **Max Mapes Ellis** | Vincennes. |
| **Samuel G. Evans** | Evansville. |
| **William P. Felver** | Logansport. |
| **Wilbur A. Fiske** | Richmond. |
| **Austin Funk** | Jeffersonville. |
| **John D. Gabel** | Madison. |
| **Andrew W. Gamble** | Logansport. |
| **H. O. Garman** | Lafayette. |
| **Charles W. Garrett** | Pittsburg, Pa. |
| **Robert G. Gillum** | Terre Haute. |
| **Vernon Gould** | Rochester. |
| **Frank Cook Greene** | New Albany. |
| **Walter L. Hahn** | Mitchell. |
| **Mary T. Harman** | State College, Pa. |
| **Victor Hendricks** | St. Louis. |
| **John P. Hetherington** | Logansport. |
| **C. E. Hiatt** | Bloomington. |
| **John E. Higdon** | Indianapolis. |
| **Frank R. Higgins** | Terre Haute. |
| **S. Bella Hilands** | Madison. |
| **John J. Hildebrandt** | Logansport. |
| **G. E. Hoffman** | Logansport. |
| **Allen D. Hole** | Richmond. |
| **Lucius M. Hubbard** | South Bend. |
| **John N. Hurty** | Indianapolis. |
| **Wm. J. Jones, Jr** | West Lafayette. |
| **O. L. Kelso** | Terre Haute. |
| **Frank D. Kern** | Lafayette. |
| **Charles T. Knipp** | Urbana, Ill. |
| **R. W. McBride** | Indianapolis. |
| **Richard C. McClaskey** | Terre Haute. |
| **N. E. McIndoo** | Lyons. |

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|---|---|
| Lynn B. McMullen | Indianapolis |
| Edward G. Mahin | West Lafayette |
| James E. Manchester | Vincennes. |
| Wilfred H. Manwaring | Bloomington. |
| William Edgar Mason | Borden. |
| Clark Mick | Berkley, Cal. |
| G. Rudolph Miller | Indianapolis. |
| Richard Bishop Moore | Indianapolis |
| Fred Mutchler | Terre Haute. |
| Charles E. Newlin | Irvington. |
| John F. Newsom | Stanford University, Cal |
| D. A. Owen | Franklin. |
| Rollo J. Peirce | Indianapolis |
| Ralph B. Polk | Greenwood. |
| James A. Price | Ft. Wayne. |
| A. H. Purdue | Fayetteville, Ark. |
| Albert B. Reagan | Mora, Wash. |
| Allen J. Reynolds | Emporia, Kansas. |
| Giles E. Ripley | Decorah, Iowa. |
| George L. Roberts | Muncie. |
| E. A. Schultze | Chicago, Ill. |
| Will Scott | Bloomington. |
| Charles Wm. Shannon | Bloomington. |
| Fred Sillery | Indianapolis. |
| J. R. Slonaker | Madison, Wis. |
| Albert Smith | Lafayette. |
| Essie Alma Smith | Bloomington. |
| C. Piper Smith | Pacific Grove, Cal. |
| J. M. Stoddard | Indianapolis. |
| Albert W. Thompson | Owensville. |
| W. B. Van Gorder | Worthington. |
| H. S. Voorhees | Ft. Wayne. |
| Frank B. Wade | Indianapolis. |
| Daniel T. Weir | Indianapolis. |
| A. E. White | Connersville. |
| Guy West Wilson | Fayette, Iowa. |
| William Watson Woollen | Indianapolis |
| Herbert Milton Woollen | Indianapolis. |

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| **J. F. Woolsey** | Indianapolis. |
| **Wm. J. Young** | Hyattsville, Md. |
| **Lucy Youse** | Terre Haute. |
| **Charles Zeleny** | Bloomington. |

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|---|---|
| Fellows | 53 |
| Non-resident members | 19 |
| Active members | 108 |
| Total | 180 |

NOTE.—For list of Foreign Correspondents, see Proceedings of 1901.

# PROGRAM

OF THE

## *TWENTY-THIRD ANNUAL MEETING*

OF THE

# INDIANA ACADEMY OF SCIENCE,

### SHORTRIDGE HIGH SCHOOL, INDIANAPOLIS.

### *NOVEMBER 28 AND 29, 1907.*

*President's Address—History and Control of Sex .......... D. M. Mottier

## GENERAL.

* 1. The Origin of Adaptation in the Fresh Water Fauna, 15m .......... C. H. Eigenmann
* 2. Spectacles—A Concession to the Theory of Evolution, 20m .......... A. G. Pohlman
* 3. New Science Laboratories in Moore's Hill College, 10m .......... A. J. Bigney
* 4. A Study in the Sex Ratio in the Fruit Fly, 15m .......... W. J. Moenkhaus
* 5. Some Photographs (Lantern Slides) of Daniel's Comet, 1907, 20m .......... W. A. Cogshall
* 6. The Celebration by the New York Academy of Sciences of the Two Hundredth Anniversary of the Birth of Linnaeus, 10m .......... G. W. Wilson
7. Hand Dexterity, 15m .......... A. G. Pohlman
8. The Autopsy in Relation to the Public Health, 12m .......... H. R. Alburger
* 9. An Investigation of the Fuel Value of Indiana Peats, 12m .......... R. E. Lyons

## ZOOLOGY.

1. Tardy Humming Birds, 5m .......... W. B. Van Gorder
*2. The Moulting Mechanism of Lizards (Lantern Slides), 20m .......... H. L. Bruner
3. A Crow Roost near Remington, Ind., 5m .......... F. J. Breese
4. The Relation of the Degree of Injury to the Amount of Regeneration and the Moulting Period in Gammarius, 15m .......... Mary Harman
5. The Influence of Environment on Man, 15m .......... Robert Hessler
*6. Some Internal Factors Controlling Regeneration in Scyphomeduson, Cassiopea Xamachana, 10m .......... Charles Zeleny
7. Selective Fertilization in Certain Fishes, 10m .......... W. J. Moenkhaus
8. Heredity in the Tumor Cell, 15m .......... H. R. Alburger
*9. The Circulation Through the Fetal Mammalian Heart, 15m .......... A. G. Pohlman
*10. The Technique of the Three Dimension Reconstruction Model, 15m .......... A. G. Pohlman
*11. Experiments on the Rate of Regeneration, 10m .......... M. M. Ellis
12. Observations on the Senses and Habits of Bats, 10m .......... W. L. Hahn
*13. Some notes on the Habits of the common Box Turtle, 5m .......... Glenn Culbertson
*14. Notes on Ecology of the Pitcher Plant .......... M. M. Ellis

## BOTANY.

*1. The Peronosporales of Indiana, 10m.......... G. W. Wilson
2. The Existence of Roestelia Pencillata and its Teliosporic Phase in North America, 15m.......F. D. Kern
3. The Heterotype Chromosomes in Pinus and Thuja, 10m..........I. M. Lewis
4. Insect Galls of Indiana, 10m..........Mel T. Cook

## GEOLOGY.

1. A Probable Origin of the Small Mounds of the Mississippi and Texas Regions, 15m.........A. B. Reagan
2. Indiana Soil Types, 10m..........C. W. Shannon
3. Structures in the So-Called "Huron" Formation of Indiana, induced by the Solution of the Mississippian Limestone Beneath, 10m..........J. W. Beede
4. Stratigraphy of the Richmond Formation of Indiana, 20m..........E. R. Cumings
*5. Some peculiarities of the Valley Erosion of Big Creek and its Tributaries in Jefferson County, 6m..........Glenn Culbertson

## PHYSICS.

*1. The Cause of Surface Tension, 10 m..........A. L. Foley
*2. Loss of Weight in Chemical Reactions, 10m..........J. B. Dutcher

## CHEMISTRY.

*1. The Electrolytic Production of Selenic Acid from Lead Selenate, 10m..........F. C. Mathers
*2. Some Complex Ureids, 5m..........James Currie
*3. Thiocarbonylsalicylamide and Derivatives, 5m..........R. E. Lyons
4. The Volumetric Determination of Selenic Acid, 5m..........R. E. Lyons

* Papers so marked were read.

# THE TWENTY-THIRD ANNUAL MEETING OF THE INDIANA ACADEMY OF SCIENCE.

The twenty-third annual meeting of the Indiana Academy of Science was held at Indianapolis, Thursday and Friday, November 28 and 29, 1907.

Thursday at 6 p. m. fifteen members of the Academy dined at the Claypool. Following the dinner the Executive Committee met in regular session at the headquarters.

At 9:30 Friday morning the Academy met in one of the rooms of the Shortridge High School. President D. M. Mottier presided. The transaction of business and the reading of papers occupied the attention of the Academy until eleven o'clock when the President read his paper on "The History and Control of Sex."

Following the address an adjournment was taken until 2 o'clock. On reassembling the business session was held after which other papers were presented and discussed. At 4:30 p. m., the program having been completed in sectional groups, the meeting adjourned to meet at some educational institution in the State outside of Indianapolis, the place to be decided by the program committee.

# In Memoriam

## LUCIEN MARCUS UNDERWOOD

BORN
NEW WOODSTOCK, NEW YORK,
OCTOBER TWENTY-SIXTH, EIGHTEEN HUNDRED FIFTY-THREE.

DIED
REDDING, CONNECTICUT,
NOVEMBER SIXTEENTH, NINETEEN HUNDRED SEVEN.

# In Memoriam

## MOSES M. ELROD

DIED
COLUMBUS, INDIANA,
MAY TWENTIETH, NINETEEN HUNDRED SEVEN.

# LUCIEN MARCUS UNDERWOOD.

## A Biographical Sketch.

Lucien M. Underwood was born October 26, 1853, in New Woodstock, New York, and died at his home in Redding, Connecticut, November 16, 1907. At the age of fifteen he entered Cazenovia Seminary, where he prepared for college. In the fall of 1873 he entered Syracuse University, graduating from this institution in 1877. His career as a seminary and as a college student was marked by unusual scholarship. In the college curriculum his favorite studies were history, mathematics and geology. During this period he began the collection of an herbarium, and, self instructed, undertook the study of the ferns. He also gave much attention to entomology.

At the time of his graduation he decided to enter the profession of teaching and for several years his work was in small institutions where he was compelled to instruct in a wide range of subjects. In 1878 he took his master's degree at Syracuse University, having completed a year's graduate work in addition to performing the arduous duties incident to the principalship of a school where he was obliged to conduct fourteen classes a day. In 1878 and 1879 he taught natural science in Cazenovia Seminary. In July of 1878 he published his first botanical paper, a list of ferns occurring about Syracuse, N. Y. From this time on his inclination to specialize in botany grew, but it was not until 1880, when he became professor of geology and botany at the Illinois Wesleyan University at Bloomington, that he had opportunity to do much botanical work.

In 1881, while at Bloomington, he published his manuscripts on ferns under the title "Our Native Ferns and How to Study Them." This publication met with great success, the sixth edition appearing in 1900. In 1883 he was called to Syracuse University as instructor in geology, zoology and botany and three years later was made professor—remaining in this position until 1890 when he secured a year's leave of absence to study the collections of hepatics in Harvard University. While in Cambridge, Mass., he accepted a professorship of botany at DePauw University. This position was the first which enabled him to devote his time to botany alone. For four years, until 1895, he enjoyed at DePauw University a period of

work under congenial surroundings, publishing numerous papers on the lower groups of plants. In 1895 he left DePauw to accept the professorship of biology in the Alabama Polytechnic Institute at Auburn. After one year at Auburn he became professor of botany in Columbia University in July, 1896, and continued in this position the remainder of his life.

Dr. Underwood was a member of the original committee on nomenclature at the Rochester meeting of the American Association in 1892 and was selected as the delegate to carry the report of the American botanists on this question to the International Botanical Congress in Genoa. He was one of the vice-presidents of the Genoa Congress. He was vice-president of the Botanical Section of the American Association at the New York meeting in 1894.

At Columbia University his career was one of great honor. He was one of the ten botanists elected at the Madison meeting of the American Association for the Advancement of Science to form the Botanical Society of America, and served as president of this organization, 1899 to 1900. From 1898 to the end of 1902 he was editor of the publications of the Torrey Botanical Club. He was associate editor of the North American Flora. He was a member of the Board of Scientific Directors of the New York Botanical Garden, serving as chairman since 1901. Syracuse University in 1906 conferred upon him the degree of Doctor of Laws in recognition of his long and distinguished scientific service. Dr. Underwood's published botanical papers and texts number 198 titles. In addition he was the author of other papers on zoology, geology, geneology and miscellaneous subjects. (See article on the published works of L. M. Underwood by John Hendley Barnhart, Bulletin Torrey Botanical Club, page 17, January, 1908.)

Dr. Underwood was a man of cheerful, genial disposition, sympathetic and helpful. He was especially kind to students and to young men in his profession and all who came in contact with him were impressed with his generosity and sincerity. He had rare power in making and keeping friends and none who has had the good fortune to enjoy his acquaintance will forget the charm of his delightful personality.

In 1881 Dr. Underwood was married to Miss Marie A. Spurr. By this union there was one daughter Miss Helen Willoughby Underwood. Dr. Underwood is survived by both wife and daughter.

During his residence in Indiana Dr. Underwood took a lively interest in the Indiana Academy of Science; contributing many valuable papers

representing a large amount of research work preparatory to a biological survey of the State. His work for the Academy was not confined to the contribution of scientific papers, but included faithful service on committees and aid in promoting the business interests of the organization. Furthermore his concern for the Academy was maintained throughout his life and after removal from the State Dr. Underwood was ever solicitous for the welfare of the Indiana Academy of Science. In the untimely death of Dr. Underwood the members of the Academy have lost a valued co-worker in science and a true and warm hearted friend whose memory will always be held in most tender regard.

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(Note.—The larger part of the data used in the above sketch was taken from "A biographical sketch of Lucien Marcus Underwood, by Carlton Clarence Curtis, Bulletin Torrey, Botanical Club, January, 1908.)

## LIST OF PAPERS CONTRIBUTED BY LUCIEN M. UNDERWOOD TO THE INDIANA ACADEMY OF SCIENCE PROCEEDINGS.

Proceedings, 1891—

- The Distribution of Tropical Ferns in Peninsular Florida, pp. 83-89.
- Some Additions to the State Flora from Putnam County, pp. 89-92.
- Connecting Forms Among the Polyporoid Fungi, by title, p. 92.

Proceedings, 1892—

- Marchantia Polymorpha. not a Typical or Representative Livewort, by title, p. 41.
- A State Biological Survey—A Suggestion for Our Spring Meeting, by title, p. 48.
- The Need of a Large Library of Reference in Cryptogamic Botany in Indiana; What the Colleges Are Doing to Supply the Deficiency, by title, p. 49.

Proceedings, 1893—

- Report of the botanical division of the Indiana State biological survey, pp. 13-19.
- Bibliography of Indiana Botany. pp. 20-30.
- List of Cryptogams at present known to Inhabit the State of Indiana, pp. 30-67.
- Our present Knowledge of the Distribution of Pteridophytes in Indiana, pp. 254-258.

Proceedings, 1894—

Report of the botanical division of the Indiana State biological survey for 1894, abstract, p. 66.

An increasing pear disease in Indiana, abstract, p. 67.

The variations of Polyporus Lucidus, abstract, p. 132.

The proposed new systematic botany of North America, abstract, p. 133.

Report of the botanical division of the Indiana State biological survey for 1894. With list of additions to the state flora, etc., pp. 144-156.

Proceedings, 1896—

Additions to the published lists of Indiana Cryptogams, pp. 171-172.

RESOLUTIONS ON THE DEATH OF LUCIEN M. UNDERWOOD, PASSED BY THE INDIANA ACADEMY OF SCIENCE, IN SESSION IN INDIANAPOLIS, NOVEMBER 29, 1907.

WHEREAS, Lucien Marcus Underwood has been a member of the Indiana Academy of Science and during his residence in Indiana took a lively interest in its affairs evidenced by notable scientific researches and contributions to its proceedings as well as by faithful services as a member of its committees and help in promoting the business interests of the Academy, and whereas, he maintained this interest in the affairs of the Academy through life after his removal from the State, and whereas, the members of this Academy held Dr. Underwood in the highest esteem as a true and warm-hearted friend;

*Be It Resolved*, That in his untimely death November 16th, we have lost a valued co-worker in science and a friend whose memory will always be held in most tender regard. Furthermore, be it resolved, That in his death America has lost one of her foremost naturalists, a botanist who has done masterful work which brought him the highest academic honors and marked recognition from his professional contemporaries everywhere. It is further

*Resolved*, That the secretary be instructed to spread these resolutions upon the minutes of the Academy and that a copy be forwarded to the widow and daughter of Dr. Underwood with whom we sympathize deeply in their great bereavement.

D. M. MOTTIER,
JOHN S. WRIGHT,
A. W. BUTLER,
Committee.

# THE HISTORY AND CONTROL OF SEX.

DAVID M. MOTTIER.

The student of sex and closely related problems of heredity may rationally ask himself any or all of the following questions: What is the significance of sex? or, in other words, why are organisms male and female? Is the sex of the organism determined during the early development of the individual? or is it predetermined in the germ cells? If the former, what conditions of the environment are favorable to the development of males and what to females? If the latter, what is it in the gametes or sex-cells that predetermines maleness or femaleness?

As in the establishment of the doctrine of sexuality itself, these questions can be answered by experiment only and by the microscopic investigation of the germ cells and the manner of their development. As an introduction to what I shall have to say in this paper concerning sex control, I desire to point out briefly those lines of study which seem to me to have been most effective in establishing the doctrine of sexuality in plants; for it will be seen that the lines of investigation which established the theory of sex are similar to those that are yielding the most fruitful results in the study of the more difficult hereditary problems of the present day.

When in the history of civilized or semi-civilized man, the idea arose that plants possess sex, no one can tell or perhaps imagine. Before the days of written history the old Arabs of the desert knew that certain palm trees produced fruit, while others did not, and, in order that the fruit might develop abundantly, it was necessary to bring the flowers of the sterile trees and hang them upon the branches of those which bore the fruit. It is evident that they also practiced the caprification of the fig, using the same methods employed at the present time in the fig-growing localities along the Mediterranean. for we read in Herodotus who, in speaking of the Babylonians, states that, "The natives tie the fruit of the male palms, as they are called by the Greeks, to the branches of the date-bearing palm, to let the gall-fly enter the dates and ripen them, and to prevent the fruit falling off. The male palms, like the wild fig trees, have usually the

gall-fly in their fruit." Herodotus was in error in regard to the presence of the gall fly in the palm, and it is said that Theophrastus was the first to point out the inaccuracy in the statement. This brilliant and gifted pupil of Aristotle was probably the foremost of all ancient botanists, for, it is said, he knew six hundred plants. The ideas of Theophrastus upon this subject seemed to be more definite than those of his great teacher. He regards the palm and terebinths as being some male and some female, for "it is certain," he says, "that among plants of the same species some produce flowers and some do not; male palms, for instance, bear flowers, the female only fruit." Let it be borne in mind here that neither Theophrastus nor the botanists of the 16th and 17th centuries considered the rudiment of the fruit to be a part of the flower. Theophrastus probably added very little to the knowledge of sexuality in plants which had been handed down to him either in the form of tradition or through the scanty writings upon natural history. That he seemed to have made no observations upon the subject, but to have relied in a large measure upon heresay, is apparent from the following: "What men say that the fruit of the female date-palm does not perfect itself unless the blossom of the male with its dust is shaken over it, is indeed wonderful. but it resembles the caprification of the fig, and it might almost be concluded that the female plant is not by itself sufficient for the perfecting of the foetus." In the time of Pliny, this idea of sexual difference in plants had been pretty well confirmed in the minds of educated men. In his "Historia Mundi," in describing the relation between the male and female date-palm, Pliny calls the pollen-dust the material of fertilization, and says that naturalists tell us that all trees and even herbs have the two sexes.

Now while the ancients had some notion of sex in plants, their ideas were based chiefly upon certain apparent analogies with animals. It must be borne in mind that whilst the ancients attributed to the pollen the power of fertilization, they had no notion that this fertilization was anything further than some unexplained subtile influence of the flower dust upon the fruit. However, we should wonder only at how much they knew in the days of Herodotus and Theophrastus as compared with the progress of knowledge made along this line during the following two thousand years: for the time from Aristotle to the discovery of the cell by Robert Hooke, the publication of the great works on anatomy by Malpighi and Grew, and the experiments of Camerarius in the latter part of the 17th century, was a lapse of long and dreary centuries in the history of science.

This was not because there were no men willing to devote their time to natural history, but chiefly because of the attitude of mind which demanded that problems arising be not solved by observation and experiment, but by the process of deductions from the authorities. The question was not, what do the observed facts teach? but, how are they to be interpreted from what Aristotle says?

The improvement of the microscope and the extensive studies on the minute anatomy of plants did not bring the results that might have been reasonably expected. In spite of his excellent work on the anatomy of plants, Grew seemed to have been unable to gain any true insight into the structure and function of pollen. He did not even consider the stamens as the so-called male members of the flower, speaking of them only as the attire, but he records a conversation with an otherwise unknown botanist, Sir Thomas Millington, who was probably the first person to claim for the stamens the character of male organs. I quote from the "Anatomy of Plants" (chap. V, secs. 3 and 4, page 171): "In discourse hereof with our learned Savilian professor, Sir Thomas Millington, he told me he conceived that the attire doth serve as the male for the generation of the seed. I immediately replied that I was of the same opinion and gave him some reasons for it and answered some objections which might oppose them." But how badly Grew must have been confused in the matter may be seen from his description of the florets in the head of certain Compositæ. He regarded the style and stigma of the floral attire as a portion of the male organ, speaking of the small globulets (pollen grains) in the thecae (anthers) of the seedlike attire as a vegetable sperm which falls upon the seed case and so "touches it with a prolific virtue." Grew could conceive of sex in plants only in the form of certain apparent analogies with animals. He reasoned that the same plant may be both male and female, because snails and some other animals are so constituted, but to complete the similarity between the plant and the animal would require that the plant should not only resemble the animal, but should actually be one. Down to the year 1691, about all that was known concerning the sexuality in plants was comprised in the facts related by Theophrastus for the date-palm and the terebinth, and in the conjectures of Millington, Grew and others, while Malpighi's views in opposition to these authors were considered equally well founded.

The doctrine of sexuality in plants could only be raised to the rank of scientific fact by experiment. It was necessary to show that no seed

capable of germination could be formed without the aid of pollen, and all historic records concur in proving that Rudolph Jacob Camerarius was the first to attempt to solve the problem in this way. Dioecious plants were cultivated apart from each other, but no perfect seeds were formed. He removed the stamens from the flowers of the castor oil plant and the stigmas from maize, with the result that no seeds were set in the castor oil plant, and in the place of grains of corn only empty husks were to be seen. The results of Camerarius were published in 1691-94. At this time the authority of the ancients was so great that Camerarius thought it necessary to insist that the views of Aristotle and Theophrastus were not opposed to the sexual theory. Among the few experiments carried out in the next fifty years were those of the Governor of Pennsylvania, James Logan, an Irishman by birth. Logan experimented with some plants of maize. Upon a cob from which he removed some of the stigmas, or silks, he found as many grains as there were stigmas remaining. One cob which was wrapped in muslin before the silks appeared, produced no kernels. In 1751, Gleditsch, director of the botanic garden in Berlin, had been told that a date palm eighty years old, which had been brought from Africa, never bore fruit. As there was no staminate tree of the species in Berlin, Gleditsch ordered pollen sent from Leipzig. The journey required nine days, and although Gleditsch thought the pollen spoiled, the male inflorescence was hung upon the Berlin tree, with the result that seeds were set which germinated in the following spring.

The century following the discovery of Camerarius was characterized by two lines of investigation which, more than any other activity of botanists, led to the complete establishment of the sexual theory. I refer to the refutation of the old theory of evolution together with the birth of the doctrine of epigenesis, and the discovery of hybridization; the first of these being the outcome of microscopic studies, and the latter that of experimentation. It may be said in this connection that the history of biological science teaches that the greatest and the most substantial progress has been made where the studies of the morphologist and of the experimenter have gone on side by side, the one serving as a control upon the other. According to the old theory of evolution, or the inclusion theory, that the germ in every seed, for example, contained all the parts of the organism, and that this germ enclosed a similar one in miniature, and so on, like a box within a box. This view of the inclusion of germ within germ was very prevalent in the 18th century, and Kaspar Friedrich Wolf (1759) has

been given the credit of refuting it. Wolf, in his doctor's thesis on the "Theory of Generation," maintained that the embryo and organs of a plant develop not by the unfolding of parts already present in miniature, but that they grew out of undifferentiated rudiments, the theory of epigenesis. However, Wolf's arguments were far from convincing, as he held that the act of fertilization was merely another form of nutrition.

About the same time experiments in hybridization were being carried on by several investigators, and the results obtained supplied much more convincing proof against the old theory of evolution. Among the foremost men in this field were Gottlieb Koelreuter and Christian Konrad Sprengel. While Kolreuter brought together many important observations on the sexuality of plants, yet his greatest service consisted in the production of hybrids. In this connection it may be of interest to note that his first hybrids were produced between two species of tobacco plants. *Nicotiana panicum* and *N. rustica*. What he accomplished did not require being changed, but when combined with later observations has been used in the discovery of general principles of hybridization. His work seems to belong to our time. Koelreuter showed that only closely allied plants, and not always these, were capable of producing hybrids, and that the mingling of parental characters in the hybrid was the best refutation of the theory of evolution. It was no easy matter to place the proper estimate upon the value of the contributions of this gifted observer. The collectors of the Linnaean school, as well as the true systematists at the close of the 18th century, who wielded a powerful influence upon botanical thought, had little understanding for such labors as Koelreuter's, and incorrect ideas of hybrids prevailed in spite of botanical literature. Hybrids were also inconvenient for the believers in the constancy of species.

Koelreuter's studies were not confined to hybridization alone, for he directs attention to the natural way of the transfer of pollen from stamen to stigma, being the first to recognize the agency of insects. He studied pollen grains, showing that fertilization followed pollenation in the absence of light, and rejected the idea that the pollen grain passed bodily into the ovary. With the microscope, however, he was less skillful than as an experimenter, for he supposed the pollen grain to be solid tissue, and the fertilizing substance to be oil which adheres to the outside of the grain and finds its way to the ovule. The pollen tube had not been discovered, although the time was one hundred years after the discovery of the cell by Robert Hooke.

As Camerarius first proved the sexuality of plants, and Koelreuter showed that different species can unite sexually to produce hybrids, so Sprengel demonstrated that a certain kind of hybridization was very common in the vegetable kingdom, namely the crossing of flowers of different individuals of the same species. To him belongs the credit for having first shown the part played by insects in cross pollenation, and pointing out the correlation between such properties of the flower as color, odor, nectar, special forms and markings, and so forth, and the visiting insects.

Karl Friederick Gaertner, son of Joseph Gaertner, took up the work so ably begun by Koelreuter, and greatly extended the knowledge of hybridization, having kept accurate account of nine thousand experiments. His work was published in 1849. Sachs states that "These observations once more confirmed the existence of the sexuality in plants, and in such a manner that it could never again be disputed. When facts were observed in 1860, which led to the presumption that under certain circumstances in certain individuals of some species of plants, the female organs might produce embryos capable of development without the help of the male, there was no thought of using these cases of supposed parthenogenesis to disprove the existence of sexuality as the general rule; men were concerned only to verify first of all the occurrence of the phenomena, and then to see how they were to be reasonably understood side by side with the existing ideas of sexuality." Gaertner's experiments were conducted at Claw, in Wurtemberg, the place in which Koelreuter carried on his studies; Camerarius worked in Tübingen.

While the experimenters in hybridization were at work, the student with the microscope was no less busy. In 1823, Amici discovered the pollen tube in the stigma, and the fact was confirmed by others. In 1830, the same observer traced the pollen tube into the ovule. Schleiden and Schacht now came forward with their erroneous theory of the formation of the embyro in the seed. They maintained that the embyro develops from the end of the pollen tube after the latter enters the ovule. It is clear that this doctrine would do away with the essential point in the sexuality of plants, for the ovule would be regarded merely as an incubator for the embyro. Amici, in 1846, brought forth decisive proof for the view he had maintained, namely, that the embryo arises not from the end of the pollen tube, but from a portion of the ovule which already existed before fertilization, and that this part is fertilized by a fluid contained in

the pollen tube. The correctness of this view was confirmed the following year by von Mohl and Hofmeister, the latter of whom described the points in detail which decided the question, and illustrated them with beautiful figures.

Following the publication of Amici, a vehement controversy arose between the adherents of the views of Schleiden and those of Amici. A prize offered by the Institute of the Netherlands at Amsterdam was awarded to an essay by Schacht in 1850, which defended Schleiden's theory, and illustrated it by a number of drawings giving both incorrect and inconceivable representations of the decisive points. In this case the prize essay was refuted before it appeared, by von Mohl, Hofmeister and Tulasne. Von Mohl's words uttered in 1863 in regard to the value of prize essays are so fitting at the present day that I can not refrain from quoting. He said: "Now that we know that Schleiden's doctrine was an illusion, it is instructive, but at the same time sad, to see how ready men were to accept the false for the true; some, renouncing all observation of their own, dressed up the phantom in theoretical principles; others with the microscope in hand, but led astray by their preconceptions, believed that they saw what they could not have seen, and endeavored to exhibit the correctness of Schleiden's notions as raised above all doubt by the aid of hundreds of figures, which had everything but truth to recommend them; and how an academy by rewarding such work gave fresh confirmation to an experience which had been repeatedly made good especially in our own subject during many years past, namely, that prize essays are little adapted to contribute to the solution of a doubtful question in science."

The discovery of the sexual process in cryptogams by Thuret, Pringsheim and others followed within four or five years after the complete establishment of that process in the higher plants. It seems strange to us now that a phenomenon so easy of observation was not discovered until its occurrence had been completely demonstrated in organisms presenting the greatest difficulties to its investigation. However, it is of interest to recall that just thirty-two years ago Strasburger traced the essential constituents of the nucleus in unbroken sequence from one cell generation to another, thus establishing for the nucleus the rank of morphological unity; and just thirty-two years ago also Oscar Hertwig showed that fertilization consists essentially in the union of the two gamete nuclei. It only remained now for later studies on the cell to confirm and to establish the doctrine that the nucleus is the bearer of the heredity characters.

With this is view, we are now ready to consider some of the modern phases of our subject.

Any effort to trace the development of the sexual process with all correlated phenomena would lead us into an overwhelming mass of details. Consequently, I shall merely recall that among the lowest plants sexuality does not exist, and that, in the simplest plants with a sexual process, the sex cells, or gametes, are scarcely to be distinguished from the nonsexual reproductive cells. The conclusion is that gametes were originally derived from a sexual propagative cells. There is accordingly no differentiation into male and female. The life cycle of these simple sexual plants is also simple, and it is reasonable to suppose that a corresponding degree of differentiation obtains in the chromatin or hereditary substances of the sex cells. As we ascend in the scale of evolution toward higher and more complex organisms, we find a corresponding differentiation in all structures and functions, and may we not assume also that the hereditary substance, or germ plasm, is likewise specialized and differentiated? Therefore, sex is the expression of a very fundamental sort of division of labor. I do not mean by that a division of labor which is of a secondary nature such as man has ascribed to the individuals of his own species, but that of a purely hereditary character—or may I say maleness and femaleness in the broadest and most fundamental sense.

How then did sex come about? And what is it that determines that one individual or member of a life cycle will be male and another female? To ask such questions fifty or even twenty-five years ago might have been regarded as visionary. Not so today. Considered from the botanical standpoint, the problem of sex determination has to deal with a certain category of phenomena that are in many respects fundamentally different from those presented by animals. In plants in which sex differentiation is well defined, there is in every complete life cycle two phases known as the sexual and the asexual, or gametophyte and sporophyte. The sporophyte springs from the fertilized egg or the union of sex cells. This sporophyte in turn bears spores which give rise to gametophytes. This may be made clear by means of an example such as the fern. The spores borne on the leaves of the fern do not produce directly new ferns, but very small plants known as prothallia, which in the simpler ferns are independent and self-nourishing individuals. The prothallia are the sexual plants. They bear the sex organs, which is turn produce eggs and sperms. The prothallia may be either purely male or female or hermaphrodite. When the egg is fertilized

it develops immediately into the sporophyte, or what we commonly know as the fern. Thus the sexual plant, or gametophyte (female gametophyte) not only produces the sex organs, but serves as the incubator and brooder for the young sporophyte. The life-cycle of the highest plants such as trees and sunflowers consists also of these two generations, but the relative size and mutual relation of sporophyte and gametophyte are different in the higher plants. For example, the beech tree is the sporophyte, the gametophyte being the pollen tube and the embryosac of the undeveloped seed. Here the reverse condition prevails as regards the mutual relation of sporophyte and gametophyte to that in the fern, namely, the sporophyte nourishes the young sporophyte as well as both gametophytes.

Now, we are in the habit of speaking of male and female flowers according as they are wholly staminate or pistillate, and the plant that bears only staminate flowers we call male, while the one bearing only pistillate flowers is designated as the female individual. However, in the strict morphological sense the sporophyte is without sex, hence trees can be neither male nor female, and to avoid trouble and useless discussion, it is doubtless better to speak of staminate and pistillate trees; for we shall see that the sex of any complete life-cycle is determined and fixed in the germ cells. From the foregoing it is quite clear that in the animal kingdom, apart from one or two cell generations, there is nothing in the life-history that is comparable to sporophyte and gametophyte.

We are now ready to answer the question, upon what does the differentiation into gametophyte and sporophyte depend? Our explanation of this doctrine is based upon the theory of the hereditary substance. Doubtless nearly all biologists concur in the view that the hereditary characters are borne by a substance in the nucleus of the cell called chromatin. When the nucleus divides the chromatin differentiates into a definite number of pieces known as chromosomes. The number of chromosomes is always constant for the reproductive cells of any species. In all the cells of the sporophyte of any plant, which lie in the germ tract, there are, let us say, a definite number of chromosomes designated by $n$. During the formation of spores, however, the number is reduced to one-half, or $n_2$. Now each spore has $n_2$ chromosomes, and the cells of the gametophyte resulting therefrom will possess $n_2$ chromosomes; consequently the egg and the sperm will have each $n_2$ chromosomes. It is apparent that when egg and sperm unite, the fecundated egg and the individual arising from it will contain $n_2$ plus $n_2$ or $n$ chromosomes.

The most fundamental difference between sporophyte and gametophyte lies in the fact that the latter possess just one-half as many chromosomes as the former. This hereditary difference between sporophyte and gametophyte and the change which brings about the transition may be made clear by means of the following figure, showing diagramatically the behavior of the chromatin. Fig. 1 illustrates the behavior of the chromatin in an ordinary vegetative cell. Here the chromatin segments passing into the new nuclei are formed by a longitudinal fission of a single chromosome—an equational division. In Fig. 2, *a* to *f*, is shown the first or reducing division in spore mother cells. One-half of the somatic chromosomes pass to one of the daughter nuclei and the other half to the other, thus bringing about the reduction of the number. The second division in the spore mother cell (*g* to *i*) is equational.

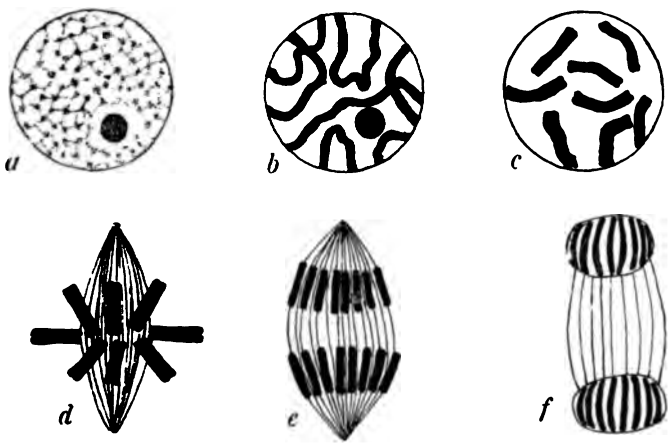


Fig. 1.

**Fig. 1. Diagrams showing the behavior of the chromatin during an ordinary somatic mitosis. *a*. nucleus in resting condition, showing chromatin distributed in small granules within the linin network and a nucleolus. *b*. the chromatin spirem has formed and it has split longitudinally. *c*. the spirem has segmented into chromosomes, e. g., eight. *d*. spindle stage; chromosomes arranged in the equatorial plate. *e*. anaphase; daughter chromo somes moving toward the poles of the spindle. *f*. daughter nuclei, each containing eight daughter chromosomes. Such a division is known as equational, since the two resulting nuclei are hereditarily alike.**

The parallel between plants and animals is found in the phenomenon of the reduced number of chromosomes in the sex-cells, with this distinction, that in higher plants the reduction in the number of the chromosomes oc-

curs when the spores are formed, which may be many thousands of cell generations removed from the time in ontogeny when eggs and sperms are differentiated; while in animals the reduction immediately precedes the formation of the gametes. In regard to the chromosomes themselves, the view generally prevailing is that each possess a distinct identity or individuality which is maintained throughout ontogeny, and phenomena pertaining thereto have been presented under the theory of the individuality of the chromosomes. Very recently, however, the idea of individuality has been taken away from the chromosomes and applied to smaller units, such as the chromomeres, or better the microscopically distinguishable granules which make up the chromomeres. We may call these particles pangens, or select any name which may be convenient and likely of adoption. The writer has expressed his views on this subject in greater detail in a recent publication, and only a few brief statements will be made here, in as much as a fuller discussion is regarded as being too technical for a general audience. The idea of individuality is applied to the chromomeres or the small particles composing them, chiefly because the identity of the chromosome is lost in the restin nucleus. There are no good reasons to believe that a given chromosome always contains the same hereditary qualities in any succession of cell generations. Furthermore, no special importance should be attached to the different sizes of the chromosomes, for, as a rule, one of the most striking phenomena in a dividing nucleus is the marked difference in the size of the chromosomes. These small material particles, or pangens, are responsible for the characters of the individual, although they are not regarded as the immediate characters themselves. They may be roughly compared with ferments, bringing about changes which collectively constitute development, and produce those chemical re-arrangements of which form, color, and so forth, are the visible expression. Fused gamete nuclei, however, do not constitute a chemical union but a mechanical mixture. The numerical reduction of the chromosomes is a consequence and a condition of sexuality. It is probably not a mere halving of the bulk of the chromatin, but a selection and a distribution between daughter cells of structural entities—the primordia of characters which are handed from one generation to another. The Mendelian principle shows, if it shows anything worth while, that these units act independently. The nucleus, therefore, directs and controls cellular development. The outer manifestations known as variation are probably due to the inter action of nucleus and cytoplasm.

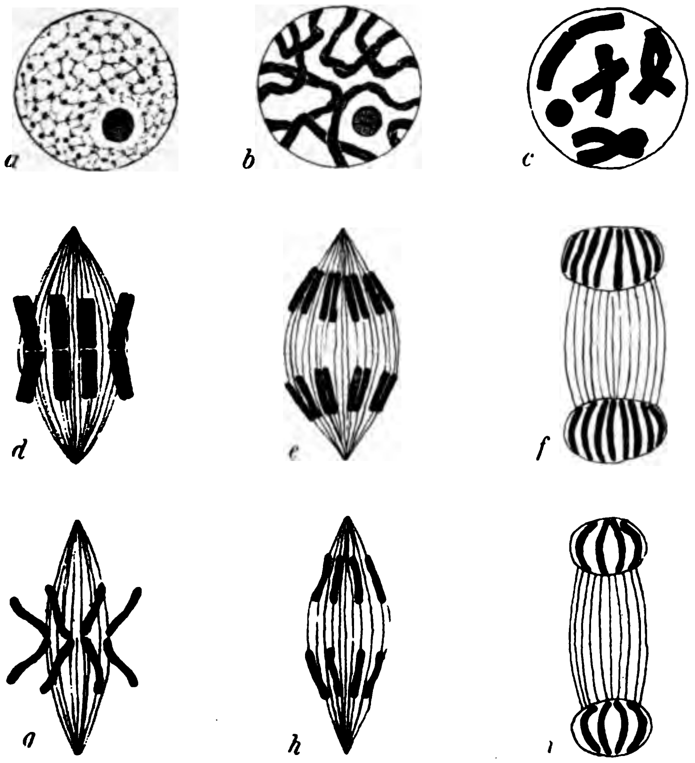

Fig. 2.

**Fig. 2. Diagrams illustrating the behavior of the chromatin during the two maturation divisions in a spore mother cell. *a—f.* first or heterotypic mitosis. *a.* resting nucleus, same as in fig. 1. *b.* longitudinally split chromatin spirem developed from *a*; the halves of the spirem are twisted upon each other. *c*, spirem has segmented into eight chromosomes which have approximated in pairs to form the four bivalent chromosomes. These eight chromosomes were united end to end in the spirem of *b*, just as in the ordinary somatic mitosis. *d.* spindle with the four bivalent chromosomes arranged in the equatorial plate. *e.* anaphase, the four chromosomes retreating towards the poles of the spindle. Each of these retreating chromosomes is now more clearly seen to be composed of two halves which were formed by the longitudinal splitting in *b*. *f.* daughter nuclei in which the spirems will be formed by the union end to end of the daughter segments. This is the division in which the number of chromosomes is reduced to one-half, because whole chromosomes pass to each daughter nucleus. If these whole chromosomes are different in hereditary characters, the division is qualitative or differential. *g—i.* second or homotypic mitosis. *g.* spindle showing the four chromosomes arranged in the equatorial plate; the free ends of the daughter segments of each chromosome diverge from each other. *h.* the segments passing to the poles of the spindle. *i.* the grand-daughter nuclei resulting from the second mitosis. This is an equasional division, because it consists of the separation of half chromosomes, or daughter segments, formed by the longitudinal fission of whole chromosomes.**

In speaking of sex, let us bear in mind that among both animals and plants there may be three kinds of individuals: Dioecious species, in which the individuals are unisexual, either male or female; monoecious, with bisexual or hermaphrodite individuals; and parthenogenetic, in which individuals produce eggs that develop without fecundation. We may now take up the question, whether the sex of the individual is determined by factors of the environment, or is it predetermined in the chromatin of the sex cells, i. e., in either sperm or egg or both? Of the environmental factors, that which is supposed to play the most important role is nutrition, and in the case of plants, it is probably the only one that need be considered, for other important factors, such as light and heat, are only influential in so far as they affect nutrition. But we should also understand that we have two sorts or two categories of environmental conditions. In case the fecundated egg develops wholly apart from the parental body, and as a completely independent individual, its supply of nourishment is from the external world; but in those cases in which the incubation of the fertilized egg and the early development of the embyro take place within the parental body, the food supply will depend upon the condition of the parent. While the conditions of these two categories seem very different, yet it will be found that the final results are essentially the same.

For the sake of simplicity, a few instances from the animal kingdom will be mentioned. Experiments were carried on by Riley and others to determine whether the starving of caterpillars of butterflies might influence the number of males and females, for under normal conditions of nutrition the caterpillars produce both males and females, and because it is not possible, says Riley, to make caterpillars take more food than they do naturally. The results of the experiments showed that an excess or diminution of food does not alter the proportion of the sexes. Upon this point Morgan (Exp. Zool., p. 377) makes the following statement: "The futility of many of these experiments has now become apparent, since it has been shown that the sex of the caterpillar is already determined when it leaves the egg. Under these circumstances it is not probable that feeding could produce a change in the sex. It is much more probable that starvation or overfeeding could only affect the proportion of males and females by bringing about a greater nortality of the individuals of one sex." Numerous studies have been made upon the silk worm by Kellog and Bell, and by Cuneot upon flies and moths, to determine the influence of food conditions upon the sex of the individual and upon that of the egg and sperm, with

the conclusion that the sex is not determined by external conditions. While the preponderance of evidence along this line seems to argue strongly against any influence upon sex-determination by food conditions, yet there is one case, that of Hydatena senta and the daphnid, Simocephalus, investigated by Nussbaum and others, in which it seemed probable that food might have some determining influence. Maupas, on the other hand, regarded temperature and not food as the influential factor. In this connection, the studies of von Malsen (Archiv. f. mikr. Anat., 69: 63-97, 1906.) upon a small worm, Dinophilus apatris, and of Issakowitsch (Idem) upon daphnids, are of especial interest. Von Malsen found that a higher temperature (26° C) was favorable to the development of males, while a lower temperature gave an increased ratio of females. He does not attribute the change in the sex ratio to the temperature directly, but indirectly as affecting the nutrition of the animal. The amount of food at the disposal of the animal was the same, but at the higher temperature, the sexual activity of the animal, i. e., the rapidity with which a large number of eggs was produced, was abnormally accelerated, so that the bodily nutrition was insufficient for the proper nourishment of the eggs. Consequently, at a higher temperature a larger number of eggs are produced, and among them is a proportionately large number of smaller or male eggs. At a lower temperature, on the contrary, reproductive activity was slower, and among the smaller number of eggs developed, a larger ratio of well nourished female eggs was the result. There was more time for the development of these eggs, and consequently more food placed at their disposal. To estimate the value of these statements it is necessary to examine the data upon which the conclusions are based. The number of eggs considered and the sexual ratio in the warm and cool cultures are shown in the following tables:

NORMAL.

| *No. of Eggs.* | *Male.* | *Female.* | *Ratio of Male : Female.* |
|---|---|---|---|
| 1140 | 327 | 813 | 1 : 2.4 |

Number of eggs at each laying, 5.6.

COOL.

| *No. of Eggs.* | *Male.* | *Female.* | *Ratio of Male : Female.* |
|---|---|---|---|
| 3948 | 973 | 2975 | 1 : 3.5 |

Number of eggs at each laying, 4.2.

WARM.

| *No. of Eggs.* | *Male.* | *Female.* | *Ratio of Male : Female.* |
|---|---|---|---|
| 1393 | 507 | 886 | 1 : 1.7 |

Number of eggs at each laying, 3.6.

At the higher temperatures it commonly happened that the eggs were developed so rapidly that the body of the animal was entirely filled from one end to the other, the head appearing as a smallpoint, the intestine so compressed as to be scarcely visible. In this condition the animal is unable to move and soon perishes. At the higher temperature, therefore, a larger number of eggs are produced so rapidly that the body can not properly nourish them. It seems to me that von Malsen's conclusions should be accepted with much reserve, because of certain probable sources of error. In the first place he seemed to have based his estimate of males and females upon the size of the eggs alone, the large ones representing females, the smaller eggs males. From the very marked variation in the size of the female eggs, as given from his own measurements, it would seem that size alone would not be a strictly accurate method of determining the sexes. In the second place it does not seem improbable that, at higher temperatures, and with a more rapid generative activity, fewer smaller eggs would fall as prey to the larger eggs; for in these animals the larger female eggs are frequently nourished at the expense of the smaller. If the nutritive activity of these large eggs is increased proportionately to the sexual activity by higher temperature, then the larger eggs should consume the smaller ones in like ratio: but von Malsen does not seem to have shown this to be true. It may be said that at lower temperatures the larger female eggs have relatively more time in which to consume the smaller, hence fewer small, or male, eggs are laid. The question then arises, does von Malsen's experiments prove that higher temperature leads to the production of more female than male eggs from the generative tissue? or merely that, at a higher temperature, ot the relatively larger number of eggs produced, a proportionately smaller number of male eggs is consumed in the nutrition of the female eggs.

The researches of Issakowitsch upon a daphnid bring us face to face with a different class of data. This author reared the descendants of parthenogenetic females through several generations (six as a maximum), and found that the production of females is paralleled with high temperature (24° C.), and that the males with lower temperature, the direct

opposite to that which happened in the worm Dinophilus. Issakowitsch shows that temperature acted merely as influencing nutrition, for when the animals were starved by being reared in distilled water, males and resting eggs were developed. From his experiments it would seem that, so far as parthenogenetic eggs were concerned, nutrition may act as a sex-determining factor. Both von Malsen and Issakowitsch look upon nutrition as a sex-determining factor from the influence it is supposed to produce upon the plasmic relation in the nucleus, as set forth by Richard Hertwig.

The more recent researches of Punnett upon Hydatena seem to throw new light upon the subject in that they point out probable errors in the studies of Maupas and Nussbaum (R. C. Punnett: Sex-determination in Hydatena, with some remarks on parthenogenesis. Proc. Royal Soc., Series B., 78: 223, 1906). In Hydatena three kinds of females may be recognized by the kinds of eggs they lay: (a) females which produce females parthenogenetically (thelytokous females); (b) females which produce males parthenogenetically (arrenotokous females); and (c) the layers of fertilized eggs. Of the first class of females, Punnett recognized from pedigree cultures three different types. A. Females giving rise to a high percentage of male producing individuals (arrenotokous females). B. Females giving rise to a low percentage of male producing individuals. C. Purely female producing individuals (pure thelytokous females).

In experiments designed to test the effect of temperature and nutrition, it was found that in the purely female producing individuals (class C), no male producing forms appeared, the strain remaining pure, and that in the class B, the ratio of males was not raised as a result of starving. Consequently it is difficult to see that either temperature or nutrition has any influence in determining male producing forms. Punnett suggests "that the females, producing females parthenogenetically (thelytokous), are really hermaphrodite, though the male gametes may not exhibit the orthodox form of spermatozoa. Such a view would account for the observed absence of polar bodies in the female eggs, for it must be supposed that the process of reduction and fertilization takes place before the accumulation of yolky material." It may be added also that if no polar bodies are formed, there is no reduction in the number of chromosomes, and we may have, as has been clearly shown in certain plants, not a case of parthenogenesis but one of apogamy. Whitney (Whitney, David Day. Determination of sex in Hydatena senta. Jrnl. Exp. Zool., 5: 1-26, 1907), in a still more recent study of Hydatena senta, finds that neither tempera-

ture nor nutrition has anything to do with the determination of sex. He asserts also that the three strains of Punnett can be found in one strain and each is capable of producing the other types according as the data is scanty or extensive.

Even if we admit that the results obtained with certain animals furnish some evidence in favor of the view that nutrition may be instrumental in determining sex, yet the vast majority of facts obtained from numerous studies made upon lower and higher plants point unmistakably to the opposite conclusion. I shall mention a few instances. Botanists have long recognized the difficulty of obtaining for class use the zygospores, or the sexually formed reproductive bodies, in the common bread mould Rhizopus nigricans, and this was supposed to be due to the lack of knowledge of the external conditions necessary to call forth sexual reproduction. Blakeslee has recently shown that this common mould is dioecious, and that if male strains are cultivated along with female strains, sexual reproduction will take place irrespective of external conditions; whereas if the different strains are grown separately, no zygospores will result, no matter what the food conditions may be. Again, the well-known liverwort, Marchantia, produces male and female sexual organs upon separate thalli, or individuals. These individuals are propagated by bodies called gemmae, and it is reported that Noll has cultivated individuals from the gemmae under all sorts of growth conditions without being able to change the sex of any of the thalli. The thalli arise primarily from spores that are apparently all alike, and that come from the same capsule, yet some of these spores must be strictly male and others female. The well-known studies of Prantl upon fern prothallia are frequently quoted as supporting the doctrine that food conditions determine sex. Prantl found that under poor conditions of nourishment the prothallia produced only male organs, and if removed to conditions affording good nourishment, female organs were developed. In this as in many similar cases, there was no change of sex since monoecious organisms were operated with, that is organisms capable of producing both male and female gametes. Lack of nourishment merely inhibited the development of the tissue upon which the female organs are borne, and consequently only male organs were developed. These prothallia arise from spores that contain the characters of both sexes, and external conditions merely stimulate the development of one or the other of the sexes, or both.

The writer has recently begun the study upon a fern, whose prothallia have been reported as strictly dioecious, and that if the spores are well

nourished female prothallia will predominate, while with poor nourishment the vast majority of spores will give rise to male gametophytes. An examination of cultures grown under favorable conditions for laboratory use, in which the spores were sown thickly, showed that certain spores produced strictly male plants, others female, and still others bisexual prothallia. A small number of spores were isolated and grown under similar and very favorable conditions, with similar results. The pure males were almost equal in number to those bearing the female organs, while the bisexual plants were few, being about four per cent. of the whole number. The foregoing results seem to lend encouragement to the view that environmental conditions may have much less to do with the development of male and female prothallia than had hitherto been supposed. The very brief study showed clearly that in the fern in question there is a great mortality among the spores, which, as can be readily seen vary greatly in size. Among the first things to establish in this and similar cases is whether mortality is greatest among the smaller or larger spores, and whether the prothallia springing from the small spores tend to remain small and produce only antheridia, while the larger female plants arise only from the larger spores, an so on. I have no notion what sort of results a careful and extended study will bring forth.

Of all efforts to ascertain the influence of the environment upon the determination of sex, doubtless the studies carried on upon dioecious plants by Strasburger and many others are the most noteworthy. Especially interesting and instructive in this connection is a representative of the pink family, the Red Campion, Lychnis dioica, which is attacked by a smut, Ustilago violaceae, whose spores are produced in the anthers instead of pollen. This red campion is dioecious, certain individuals bearing only staminate and others pistillate flowers. The structure of the staminate and pistillate flowers are shown in the following figure.

If a plant, bearing staminate flowers, be infected by the smut, the anthers when mature will be filled with smut spores instead of pollen. Apart from the color of the anthers the form of the staminate flower is unchanged by the presence of the parasite. On the other hand, if a plant, bearing pistillate flowers, is befallen by the smut, the blossoms on the branches affected by the smut, will develop normally appearing stamens, whose anthers are filled with smut spores instead of pollen, while the pistil remains in a rudimentary condition. The only apparent difference between a pistillate flower thus affected by the parasite and the normal staminate

blossom is an elongation of the axis between calyx and corolla (Fig. 3b′). At first sight it might appear that the presence of the parasite was sufficient to change the sex of the plant, for the fungus, when present in the pistillate plant, leads regularly to the development of stamens and the suppression of the pistil. However, in this case the capacity to develop stamens must be assumed to be present in the pistillate plant, and the parasite is able to induce the conditions necessary to their formation and the suppression of the pistil, and thus provide for the development of its own spores. Extensive and elaborate experiments by Strasburger upon uninfected plants with the view of duplicating the effects produced by the parasite, led to no definite results.

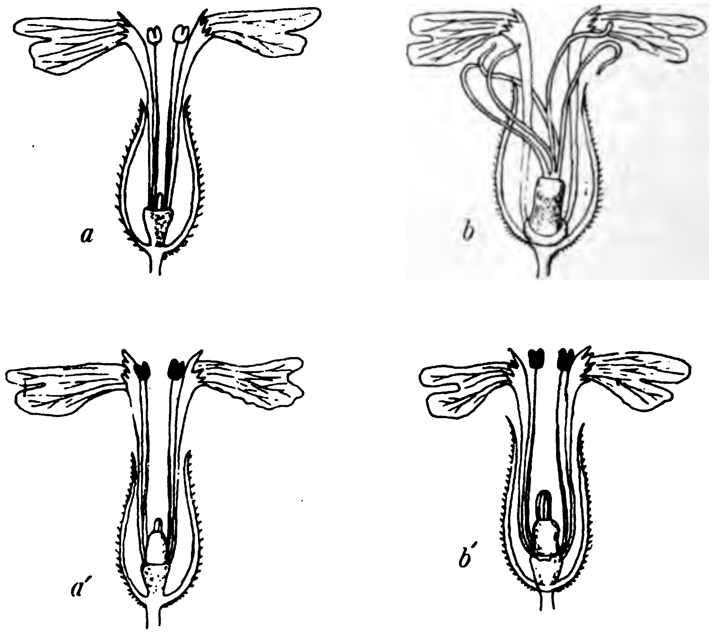


Fig. 3.

Fig. 3. Staminate and pistillate flowers of Lychnis dioica L., halved longitudinally. a. normal staminate flower. b. normal pistillate flower. a′ staminate flower affected by the smut, Ustilago violaceae; the anthers contain smut spores instead of pollen. b′ pistillate flower similarly affected: the pistil has remained rudimentary while anthers have been developed, which, however, bear only smut spores. The presence of the parasite has induced the development of anthers, the members of the flower bearing male spores instead of the parts bearing the female spores.—After Strasburger.

Laurent (1903) has maintained that an excess of nitrogen or lime favors the development of males in spinach, hemp, etc., while potash and phosphoric acid favor the development of females, but his results are not very convincing. Temperature, light and moisture conditions, relative age and vigor of parents, relative maturity of pollen, early and late planting, pruning, etc., have all been carefully and elaborately tested without achieving satisfactory or convincing results. The case of the anther smut cited in the foregoing seems to furnish the best evidence among plants that the sex of the spores to be developed can be changed by environmental conditions, yet it must be admitted that the preponderance of evidence is against the view that environmental conditions, either direct or indirect, can determine sex. On the other hand, there are many who believe that sex is predetermined in the germ cells, and that we are confronted with a problem which is purely hereditary. According to this view certain parts of the hereditary substance or chromatin contain male characters, or repesent maleness only and certain other parts female characters, or femaleness, that is, there are male determinants and female determinants in the chromatin. To illustrate this statement, let us recall the case of the common liverwort, Marchantia. Of the spores produced by any individual sporophyte, some will give rise only to male thalli and others to female thalli irrespective of environmental conditions. Now, the spores producing only male plants must contain only male determinants, or male determining parts of the chromatin must dominate over the female determinating parts in those spores and vice versa. If the determination of sex be regarded as a problem of heredity, and if we believe that hereditary phenomena have a physical basis, some such theory as the foregoing certainly affords a rational basis for further investigation.

# The Celebration by the New York Academy of Sciences of the Two Hundredth Anniversary of the Birth of Linnaeus.

Guy West Wilson.

The two hundredth anniversary of the birth of Linnaeus, the great Swedish naturalist whom we regard as the father of modern biology, was fittingly commemorated by the New York Academy of Sciences. For some time the officials of that organization had been perfecting plans for the observance of this anniversary. Perhaps few other societies in America have at their command the resources for a celebration which would parallel this one, as the New York Academy has affiliated with it all the learned societies of the Greater City and has at its disposal for such an occasion the magnificent museums of the metropolis. It accordingly gave me no small pleasure to receive the honor which the president of the Indiana Academy of Science conferred upon me in asking me to represent this body at these exercises.

At 9:30 a. m. of the 23d of May the delegates from numerous American and foreign societies and institutions met in the trustees' room of the American Museum of Natural History, and, in company with the officers of the New York Academy, proceeded in a body to the lecture room where the initial meeting was held. About three-quarters of an hour was devoted to the reading of communications from the societies whose delegates were present, and from a few noted foreign societies which were not represented. These communications covered a wide range of topics, extending from greetings from the various societies through outlines of the character of their work and eulogies to the memory of Linnaeus to monographic considerations of some phase of the work of Linnaeus. Of these last may be mentioned the papers presented by the representatives of the Brooklyn Entomological Society and of the Maryland Academy of Science. The first of these related to the entomological work of Linnaeus and its relation to American entomology, while the second was a learned and interesting discussion of Linnaeus and the flora of Maryland. This part of the program was followed

by a learned address by Dr. T. A. Allen of New York on "Linnaeus and American Zoology," which forms a most valuable contribution to the history of zoology.

At the close of these exercises the delegates proceeded in a body to "La Hermatage," a quaint little French hotel in the Borough of the Bronx near the New York Botanical Garden. Here the party was joined by the Swedish Minister to America and the members of the Swedish Legation in New York City. After dining together the party returned to the lecture room in the Museum building of the New York Botanical Garden. The first address of the afternoon, "Linnaeus and American Botany," was delivered by Dr. P. A. Rydberg, a fellow countryman of Linnaeus. This address dealt in a masterly and interesting manner with the sources of Linnaeus' information concerning American plants, closing with a discussion of the genus *Linnaea* which was at first supposed to contain a single species, but to which subsequent exploration and study added two others. To these a fourth was added from Arctic America. The second and closing address of the afternoon was delivered by Dr. H. H. Rusby on the "Flowers of North American plants known to Linnaeus." This lecture was made doubly interesting by the fine display of lantern slides by which it was accompanied. These belonged to the Van Brunt collection of the Botanical Garden, which is one of the finest and most complete collections of hand painted lantern slides of American plants.

After these exercises a walk of about three-quarters of a mile through the magnificent natural forest of Bronx Park brought the party to the Linnaen bridge on Pelham Parkway. The party was conducted by Dr. W. A. Murrill, who pointed out a number of characteristic American trees known to Linnaeus. At the bridge a tablet to the memory of Linnaeus was unveiled. Appropriate addresses were made by several persons of note and the key to the tablet which contained various articles of scientific interest was given to the New York Historical Society for safe keeping until the 23d of May, 1957, when another anniversary celebration is to be held and the contents of the tablet examined. The members of the staff of the New York Zoological Garden then conducted the party through their grounds, showing the collections with especial reference to the American animals known to Linnaeus.

The evening program consisted of a reception at the Aquarium in Battery Park and of a series of addresses at the Brooklyn Museum of Arts

and Sciences. The first of these was of great interest as it was the first occasion upon which this magnificent collection had been viewed at night. It was also the centennial of the building which has seen a varied career of fort, amusement place, emigrant landing and repository of scientific collections. The second part of the program was taken up with several addresses, but three of which need to be mentioned. The first was by Professor E. L. Morris on the "Life of Linnaeus," and was pronounced by his hearers a masterpiece of biography. This was followed by an address upon "Linnaeus and American Natural History," by Dr. F. A. Lucas who treated his subject in a most interesting manner. The program was closed by a talk by Dr. T. A. Grout on the "Plants and Animals Known to Linnaeus," which was profusely illustrated by lantern slides.

Another feature of great interest in connection with this celebration was the series of exhibits of objects of American natural history known to Linnaeus. At the American Museum of Natural History extensive exhibits were arranged to show the American animals and the rocks and minerals known to Linnaeus and arranged according to his system of classification, a full explanation of which accompanied the exhibit. At the New York Botanical Garden there was a large collection of American plants known to Linnaeus and arranged according to his system of classification. Accompanying this exhibit was a very complete set of the botanical works of Linnaeus and a very fine series of portraits of him. Enjoyable and profitable as were all the other features of this celebration these exhibits and the lectures by Dr. Busby and Dr. Grout added much to the value and interest of the celebration and to the delightful remembrances which the delegates carried home with them.

New York City.

# An Investigation of the Fuel Value of Indiana Peat.

Robert E. Lyons.

Peat is a moist, spongy, partially carbonized vegetable matter. It is an incipient coal* containing the heat units stored up by the vegetation from which it is formed. This form of crude fuel has been used in Europe for centuries and today is used in Canada and in some places in the United States.

Hundreds of thousands of acres of peat beds exist in the lake region of Indiana embraced within the three or four northern tiers of counties. These deposits constitute a source of cheap and easily obtained fuel for local use. As the price of coal advances the use of peat for the manufacture of briquettes will increase and the time will doubtless come when the cities in that portion of the state will derive their fuel from the peat bogs of that region.

It has recently been my privilege to investigate the fuel value of a number of representative samples of Indiana peats which were collected by the State Department of Geology and Natural Resources. The relative fuel value of each of twenty-nine samples was determined by calorimetric test with the Parr Standard Instrument and the results expressed in British Thermal Units. (B. T. U. = the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.) The results are also expressed in calories; a calorie being the amount of heat required to raise one gram of water one degree centigrade. The test was made on samples of peat dried at 105° Cent., which give a slightly higher thermal effect than would be obtainable in the practice with air dried peat, because of the moisture held by peat even after prolonged air

*The following table from Ost, Technische Chemie, 1903, p 12, indicates the progressive changes which peat might undergo in a possible conversion to anthracite coal:

| | *Wood.* | *Peat.* | *Lignite.* | *Bituminous Coal.* | *Anthracite Coal.* |
|---|---|---|---|---|---|
| Carbon | 50 | 60 | 70 | 82 | 94 |
| Hydrogen | 6 | 6 | 5 | 5 | 3 |
| Oxygen | 43 | 32 | 24 | 12 | 3 |
| Nitrogen | 1 | 2 | 1 | 1 | Trace. |

drying under favorable conditions. The advantage in using oven dried peat in the calorimetric test is that all samples may be accurately compared as to heating effect. The amount of moisture remaining after air drying is dependent upon local conditions.

TABLE SHOWING THE FUEL VALUE OF TWENTY-NINE SAMPLES OF PEAT FROM NORTHERN INDIANA.

| Number. | County, Township, Range and Section. | B. T. U., Oven Dried 105°C. | Calories, Oven Dried 105°C. | Evaporative Effect Pounds Water per Pound of Oven Dried Peat. |
|---|---|---|---|---|
| 1 | Dekalb Sec. 9 (33 N., 12 E.) | 10232.77 | 5684.8 | 10.6 |
| 2 | Steuben, Sec. 34 (37 N., 12 E.) | 9422.87 | 5234.3 | 9.7 |
| 3 | LaGrange, Sections 2, 11 and 12 (36 N., 8 E.) | 8513.29 | 4729.5 | 8.8 |
| 4 | LaGrange, Sections 4 and 9 (37 N., 9 E.) | 8924.47 | 4958.0 | 9.2 |
| 5 | Noble, Sections 28 and 29 (33 N., 9 E.) | 10335.57 | 5741.9 | 10.7 |
| 6 | Noble, Sec. 18 (33 N., 11 E.) | 9217.28 | 5120.7 | 9.5 |
| 7 | Whitley, Sec. 30 (31 N., 10 E.) | 4541.67 | 2523.1 | 4.7 |
| 8 | Kosciusko, Sections 11, 12 and 13 (31 N., 6 E.) | 9715.68 | 5397.6 | 10.0 |
| 9 | Kosciusko, Sections 32 and 33 (33 N., 6 E.) | 6129.32 | 3405.1 | 6.3 |
| 10 | Elkhart, Sec. 4 (36 N., 5 E.) | 8637.89 | 4799.4 | 8.9 |
| 11 | Elkhart, Sections 10 and 11 (36 N., 6 E.) | 7211.22 | 4006.0 | 7.4 |
| 12 | Elkhart, Sections 26 and 27 (35 N., 5 E.) | 7613.06 | 4229.4 | 7.8 |
| 13 | Elkhart, Sec. 18 (38 N., 6 E.) | 9628.78 | 5349.3 | 9.9 |
| 14 | St. Joseph, Sections 28, 33 and 34 (36 N., 2 E.) | 9840.28 | 5466.8 | 10.1 |
| 15 | St. Joseph, Sec. 3 (36 N., 1 E.) | 9024.15 | 5013.4 | 9.3 |
| 16 | St. Joseph, Sections 11 and 12 (37 N., 1 E.) | 8503.95 | 4724.4 | 8.8 |
| 17 | St. Joseph, Sec. 16 (37 N., 2 E.) | 8236.06 | 4584.4 | 8.5 |
| 18 | St. Joseph, Sec. 20 (37 N., 2 E.) | 8491.49 | 4717.5 | 8.8 |
| 19 | Marshall, Sections 10 and 11 (33 N., 1 E.) | 9946.19 | 5525.6 | 10.3 |
| 20 | Marshall, Sec. 1 (34 N., 2 E.) | 8497.72 | 4720.9 | 8.8 |
| 21 | Marshall, Sec. 10 (34 N., 1 E.) | 10466.40 | 5814.6 | 10.8 |
| 22 | Starke, Sec. 10 (32 N., 3 E.) | 9905.70 | 5503.1 | 10.2 |
| 23 | Pulaski, Sec. 9 (31 N., 1 W.) | 9774.87 | 5430.4 | 10.2 |
| 24 | Pulaski, Sections 7, 8 and 9 (31 N., 3 W.) | 9064.65 | 5035.9 | 9.3 |
| 25 | Pulaski, Sections 3, 9, 10 and 11 (31 N., 4 W.) | 8472.80 | 4707.1 | 8.7 |
| 26 | Porter, Sections 1, 2 and 3 (37 N., 5 W.) | 5635.03 | 3130.5 | 5.8 |
| 27 | Jasper, Sections 12, 13 and 14 (30 N., 6 W.) | 8273.44 | 4596.3 | 8.0 |
| 28 | Newton, Sections 32 and 33 (31 N., 8 W.) | 9033.50 | 5018.9 | 9.3 |
| 29 | Lake, Sections 34, 35 and 36 (35 N., 9 W.) | 8731.34 | 4850.7 | 9.0 |

The results of the tests show the moss peats to have a much higher heat value than the peats of the grass and sedge variety. This fact is corroborated by numerous other tests on peats from other regions.

Five typical specimens of peat were subjected to a more complete chemical analysis, including the determination of the percentage of moisture, volatile combustible matter, fixed carbon, coke, ash, sulphur and nitrogen.

CHEMICAL ANALYSES OF FIVE SAMPLES OF PEAT FROM NORTHERN INDIANA.

| Number. | County, Township, Range and Section. | Moisture 105°C. | Volatile Air Dried. | Fixed Carbon, Air Dried. | Coke Air Dried. | Ash Air Dried. | Nitrogen Air Dried; | Sulphur, Oven Dried |
|---|---|---|---|---|---|---|---|---|
| 1 | Dekalb, Sec. 9 (33 N., 12 E.). | 17.16 | 73.31 | 22.53 | 26.67 | 4.14 | 2.56 | 0.74 |
| 14 | St. Joseph, Secs. 28, 33 and 34 (36 N., 2 E.) | 12.24 | 70.21 | 23.45 | 29.78 | 6.33 | 2.22 | 0.87 |
| 15 | St. Joseph, Sec. 3 (36 N., 1 E.)........... | 11.40 | 65.52 | 20.65 | 34.47 | 13.82 | 3.31 | 1.33 |
| 19 | Marshall, Secs 10 and 11 (33 N, 1 E.).... | 8.99 | 70.97 | 19.08 | 29.09 | 10.01 | 3.91 | 0.83 |
| 22 | Starke, Sec 10 (33 N, 3 E)........... | 10.20 | 62.43 | 24.30 | 37.55 | 13.25 | 2.96 | 0.96 |

The value of any fuel depends upon the quantity of heat generated and the temperature which can be obtained. The influence of moisture and ash upon the heating power of peat is well shown in the following table*:

| | |
|---|---|
| Dry peat without ash .................................... | 6500 calories |
| Dry peat with 4% ash .................................... | 6300 calories |
| Dry peat with 12% ash .................................... | 5800 calories |
| Dry peat with 30% ash .................................... | 4500 calories |
| Same peat with 25% water .................................... | 4700 calories |
| Same peat with 30% water .................................... | 4100 calories |
| Same peat with 50% water .................................... | 2700 calories |
| Same peat with 0% water and 15% ash .................. | 5500 calories |
| Same peat with 25% water and 0% ash .................. | 4700 calories |
| Same peat with 30% water and 10% ash .................. | 3700 calories |

It will be noticed that the difference between two samples of peat having a different content of moisture is greater than that due merely to the displacement of combustible matter. The loss represents the amount of heat consumed in vaporizing the moisture. This demonstrates the necessity of preparing peat for use as fuel so as to contain the least possible amount of moisture.

A comparison of the heating power of peat and various other fuels is given in the following tables†:

* Hausding, Handbuch der Torfgewinung, 1904, p. 333.

† First table from Hausding. Second table from Thurston's Elements of Engineering

| | Water Chemically Combined. | Water Mechanically Held. | Ash. | Calories. |
|---|---|---|---|---|
| Anthracite coal | 2 | 3 | 2 | 8305 |
| Charcoal, air dry | 0 | 12 | 3 | 6868 |
| Charcoal, kiln dry | 0 | 0 | 3 | 7837 |
| Wood, air dry | 39 | 20 | 1 | 3232 |
| Wood, kiln dry | 49 | 0 | 1 | 4040 |
| Peat | 26 | 25 | 5 | 3950 |
| Peat, manufactured | 30 | 18 | 2 | 4430 |

| | B. T. U. | Evaporative Effect. |
|---|---|---|
| Coal, anthracite | 14833 | 14.98 |
| Coal, bituminous | 14796 | 14.95 |
| Coal, lignite, dry | 10150 | 10.25 |
| Peat, kiln dry | 10150 | 10.25 |
| Peat, air dry | 7650 | 7.73 |
| Wood, kiln dry | 8020 | 8.10 |
| Wood, air dry | 6385 | 6.45 |

From these tables it will be seen that unprepared peat has a higher heating value than wood, but is inferior to coal.

## COMPARISON OF INDIANA BITUMINOUS COALS AND INDIANA PEATS.

I. CHEMICAL COMPOSITION:

(A) The extreme percentages of the constituents considered in connection with the fuel value of twenty samples of Indiana coal, analyzed by Dr. W. A. Noyes*:

| | Moisture 105°. | Volatile Combustible Matter. | Fixed Carbon. | Coke. | Ash. | Sulphur. |
|---|---|---|---|---|---|---|
| Maximum | 13.82 | 45.16 | 52.77 | 57.22 | 9.76 | 4.01 |
| Minimum | 6.08 | 35.22 | 41.80 | 49.62 | 1.06 | 0.34 |

(B) Similar data from the analyses of Indiana peats (air dried):

| | | | | | | |
|---|---|---|---|---|---|---|
| Maximum | 17.16 | 61.98 | 24.30 | 37.55 | 13.82 | 1.33 |
| Minimum | 8.99 | 52.23 | 19.08 | 26.67 | 4.14 | 0.74 |

*Report of State Geologist, 21, p. 105.

II THE HEATING AND EVAPORATING EFFECT AS SHOWN BY THE CALORIMETRIC TEST:

(A) Data from twenty samples of Indiana coal analyzed by Dr. W. A. Noyes*:

| | *B. T. U.* | *Calories.* | *Evaporative Effect.* |
|---|---|---|---|
| **Maximum** | 13219 | 7344 | 13.4 |
| **Minimum** | 11691 | 6495 | 12.1 |
| (B) Data from twenty-nine samples of Indiana peat (oven dried): | | | |
| **Maximum** | 10466 | 5814 | 10.8 |
| **Minimum** | 4541 | 2523 | 4.7 |

SUMMARY.

| | *Calories.* | *Evap. Effect.* |
|---|---|---|
| 1 lb. best of 20 samples Indiana coal tested yields | 7344 | 13.4 |
| 1 lb. best of 29 Indiana peat tested (oven dried), yields. | 5814.6 | 10.8 |
| 1.26 lbs. best Indiana peat (No. 21) equals in thermal effect 1 lb. of the best Indiana coal (No. 17, Report State Geologist, 21, p. 106). | | |
| 1 lb. oven dry peat, average of 29 samples, yields | 4288 | 8.0 |
| 1 lb. coal, average of 20 samples, yields | 6860.8 | 12.8 |
| 1.6 lbs. average peat (oven dry) equals in thermal effect 1 lb. of average Indiana coal. | | |

The cost of preparing the peat, or pressing it into briquettes, must be considered in a comparison of peat with coal. Some peat briquetting plants are already in operation in Indiana, e. g. The Indiana Peat Co. of North Judson, Starke County. This firm estimates the operating expenses for a small peat plant of thirty tons capacity, as follows:**

| | |
|---|---|
| 1 foreman | $3 00 |
| 1 engineer | 2 75 |
| 2 peat men | 4 00 |
| 4 boys | 5 00 |
| 1 man, hoisting engine | 1 50 |
| 2 men at press | 4 00 |

*Report of State Geologist, 21, p. 105.
**Report of State Geologist, 31, p. 99.

| | |
|---|---|
| 1 night man ................................... | $1 50 |
| Office ............................................ | 5 00 |
| Total ........................................ | $26 75 |

According to this estimate the manufacturing of peat into briquettes costs about 85 cents per ton.

## PEAT AS A SOURCE OF PRODUCER GAS.

In ordinary direct firing the object is to effect complete combustion in proximity to the fuel bed. Within the same chamber the fuel elements are vaporized, distilled, gasified and completely burned. The first two processes absorb heat only and there are advantages in separating them from the point where combustion of the gases occurs and where high temperatures are developed by the heat evolved. The gas producer or generator accomplishes this. Within it vaporization, distillation and gasification result in a combustible gas, which, led away to a separate combustion chamber, is there burned under conditions favoring a fuller realization of the fuel value and the attainment of temperatures otherwise impossible.

Even with a close connection of producer to the furnace, and consequent utilization of the sensible heat of the gas, there is a loss of energy, but it should not exceed 15 to 18 per cent. of the calorific value of the fuel. Notwithstanding this loss, experience has demonstrated that producer gas accomplishes the same result with less fuel. It has made possible metallurgical operations which were impractical with direct firing, and materials quite unsuited for heating operations are made available by previous gasification in a producer. This is true of combustible substances containing much moisture, as wood, sawdust, peat, etc. The water may be removed from the gases, which can then be applied to operations requiring high temperature.

The yield of producer gas from different fuels varies within wide limits.*

| *Material.* | *Gas Yield per Pound in Cubic Feet.* |
|---|---|
| Coke or charcoal ................................ | 104 |
| Bituminous coals ................................ | 75 |
| Brown coal ............. ...................... | 55 |
| Turf ................................................ | 45 |
| Wood ............................................ | 35 |

*R. D. Wood, Industrial Applications of Producer Gas, p. 25 and p. 26.

It has been demonstrated by test at the United States coal testing station in St. Louis that Indiana bituminous coal can be converted into producer gas and that when this gas is burned in a gas engine it yields 2 to 2½ times as much energy as could be obtained from burning the same coal under a boiler.

The advantages of burning coal gas pertain equally to using peat as a gaseous fuel. The use of solid peat fuel involves a loss of more than 25% of heat, which loss may be reduced to about 15% by first converting the peat into gas and then burning the gas.

Peat gas is valued above coal gas in the steel industry on account of its greater freedom from sulphur and phosphorus.

R. D. Wood & Co., of Philadelphia, have made experiments on the application of Texas lignite in gas producers and have demonstrated its value as a basis of gas production. This lignite is not far removed in its chemical composition from peat. Lignite showed moisture 21.86, volatile matter 31.81, fixed carbon 36.85, ash 9.48. The gas made from it is high in hydrocarbons, and, as a consequence, its flame produces an intense heat.*

A test of "machine peat" from Taunton, Mass., gave 4 cu. ft. of gas with a calorific power of 654 B. T. U. per cu. ft. from each pound of peat.† Gas from "cut peat" averages about 135 B. T. U.

‡One ton of compressed peat analyzing: moisture 15, ash 7, fixed carbon 21, volatile matter 57, will yield not less than 100,000 cubic feet of gas of not less than 150 B. T. U. per cubic foot.

Effort is now being made to utilize part of the peat deposits of Ireland by using peat for gas producer fuel in electric plants with recovery of ammonia and other by-products.‖ It is estimated that from 85 to 150 pounds of ammonia sulphate can be obtained per ton of peat with 1,780 cu. meters of gas. Acetate of lime, naphta, paraffin and volatile oils are also obtained. One hundred pounds of dry peat are calculated to yield 675,000 B. T. U. realizable as gas in a Mond producer, which would give 76 indicated horsepower hours in a gas engine, assuming a 30% thermal efficiency.

Caro¶ has recently improved the well-known Mond process for making producer gas in so far as he gasifies poor fuel in a mixture of air

*R. D. Wood, Industrial Applications of Producer Gas, p. 25 and p. 26.
†Norton: Report XV, Bog Fuel.
‡Twelfth Report Ontario Bureau of Mines, p. 231.
‖Jour. Gas Lighting, 100, p. 760.
¶Elektr. Zeitschrift, March, 1907.

and superheated steam. Extended experiments with this modified process in the Mond works at Stockton show that it is possible to treat directly wet peat, containing 50% to 55% water, with a simultaneous increase of ammonium sulphate. The chief result in the success of this undertaking is to render available the use of wet non-briquetted peat in gas producers, while the ammonium sulphate obtained as a by-product will assure in itself a fair interest on the capital invested.

Data concerning producer gas made from Indiana peat is not available at the present time. There is, however, no apparent reason why it should not be as satisfactorily used.

In the opinion of the writer, the greatest development of the peat fuel industry in Indiana will doubtless be as a source of producer gas.

# Notes on the Humming Bird.

W. B. VanGorder.

From information gathered through various sources the humming bird is not often seen in Indiana after the middle of September of each year, most of them leaving much earlier than this, while a few tarry longer, even to the last of September. September 29 is the latest date of their appearance in the State as given by Mr. Butler in his report of the birds of Indiana. On September 8 I noticed one about the flowers in my garden; also one on September 9. On September 15 I noticed one again. This attracted my attention, as I had marked September 9 for the last date for 1907. I decided now to watch more closely the flowers in my garden and in my neighbor's garden adjoining.

This was the result of my observations: The daily visits of these birds being as follows: September 15, three visits; September 16, two visits; September 17, three visits; September 18, three visits; September 19, two visits; September 20, two visits; September 21, none; September 22, two visits; September 23, one visit at 4:30 o'clock in the afternoon; September 24, one visit at fifteen minutes past twelve, one at twenty minutes of five o'clock and one at 5:30 o'clock; September 25, one at seven o'clock in the morning; September 26, one visit at seven o'clock in the morning and one at twenty minutes past twelve; September 27, one visit at 6:30 in the morning; September 28, one visit at eight o'clock and one at nine o'clock; September 29, one visit at fifteen minutes of eight, one visit five minutes past nine, one at five minutes past ten, one at ten thirty, one at eleven forty, one at ten minutes of four, one at four thirty and one at five o'clock; September 30, one visit at twenty-five minutes past twelve; October 1, one visit at twelve o'clock and one at four thirty; October 2, one at three thirty; October 3, one at twelve twenty; October 4, one at five minutes of twelve and one at twenty minutes past twelve; October 5, I watched two hours before I saw a humming bird at ten thirty, another visit at ten fifty and at five fifteen, one hovering about a few nasturtiums; October 6, one visit at one o'clock, one at one-thirty and one at five o'clock. October 7 it rained all day and none was seen.

October 8 at five minutes past twelve, two came from the north and tarried a few minutes about a bed of cannas and together flew direct south. October 9 I saw one at twelve thirty hovering about the cannas. It came from the north and flew to the south. I had noticed the flower garden was approached by these birds from all directions up to the last two days, when the visits were made as stated. As I was engaged in school work my observations did not cover the whole day except in a few cases, but the record here given is my own.

On October 1 a few persons were asked to make observations, which they did, and with about the same results as here stated. Two of the stations were more than two miles apart. Three reported seeing these birds on October 8 and one on October 9.

It is often stated that the temperature governs the movements of these birds. The temperature for the time as reported to the weather bureau by Mr. Charles Geckler is as follows:

| | *Maximum.* | *Minimum.* | | *Maximum.* | *Minimum.* |
|---|---|---|---|---|---|
| September 15.......... | 87 | 62 | September 30.......... | 76 | 41 |
| September 16.......... | 87 | 63 | October 1.............. | 81 | 41 |
| September 17.......... | 88 | 63 | October 2.............. | 83 | 56 |
| September 18.......... | 90 | 66 | October 3.............. | 81 | 62 |
| September 19.......... | 90 | 65 | October 4.............. | 73 | 67 |
| September 20.......... | 89 | 62 | October 5.............. | 75 | 45 |
| September 21.......... | 83 | 62 | October 6.............. | 76 | 42 |
| September 22.......... | 75 | 49 | October 7.............. | 71 | 56 |
| September 23.......... | 81 | 43 | October 8.............. | 66 | 45 |
| September 24.......... | 80 | 56 | October 9.............. | 68 | 37 |
| September 25.......... | 65 | 36 | October 10............. | 68 | 36 |
| September 26.......... | 71 | 38 | October 11............. | 63 | 50 |
| September 27.......... | 81 | 50 | October 12............. | 56 | 37 |
| September 28.......... | 78 | 58 | October 13............. | 55 | 31 |
| September 29.......... | 59 | 53 | | | |

The record for a few days past their last appearance is given for the sake of comparison.

There was a white frost on the morning of September 25; also on the morning of October 9. It is also stated these birds will remain as long as there are flowers. There was an abundance of flowers until October thirteen, when there was a killing frost.

# The Moulting Mechanism in the Heads of Lizards.

By H. L. Bruner.

(Abstract.)

One of the muscles of this mechanism was described before the Academy of Science several years ago (1). The complete mechanism, which I have recently described in the American Journal of Anatomy (2), includes the following more important parts:

1. The veins and blood sinuses of the head.

2. Special muscles which distend the sinuses and raise the venous blood pressure. One of these muscles (m. constrictor venae jugularis internae) invests the chief cephalic vein at the point where it passes from the head into the neck. A second muscle (m. protrusor oculi) lies behind the orbit in close relation to the large orbital sinus.

3. The cardio-accelerator mechanism. During the operation of the moulting mechanism the number of heart-beats increases and a larger amount of blood is sent to the head.

In the operation of the moulting mechanism two stages occur. The first stage is characterized by contraction of the constrictor muscle and by acceleration of the heart-beat. The veins and sinuses of the head are distended with blood; the eyes protrude. The second stage is caused by contraction of the protrusor muscle and others which press upon the distended vessels and raise the blood pressure to a higher level.

The distension of vessels and elevation of blood pressure aid in exuviation by stretching the skin and by facilitating the processes of metabolism. The moulting mechanism may be set in motion in an experimental way by the application of court plaster, or similar material, to the head.

In snakes and turtles the imternal jugular vein is provided with a constrictor muscle, but the protrusor oculi is wanting. The simpler mechanism of these forms probably has the same function as the more complicated apparatus of the lizards.

1 Proc. Ind. Acad. Science, 1898, p. 229.

2 Am. Jour. Anat., Vol. VII, 1907, pp. 1-117.

# The Relation of the Degree of Injury to the Rate of Regeneration and the Moulting Period in the Gammarus.

Mary T. Harman.

## INTRODUCTION.

In 1905 in some experiments on the crayfish, Zeleny found that in the series of crayfish with the greater degree of injury each chela regenerated more rapidly than the chela in the series with the lesser degree of injury. He also found that the members of the series with the greater degree of injury moulted more rapidly than the members of the series with the lesser degree of injury. In 1906, in some experiments on the lobster, Emmel found that in the series of lobsters with the lesser degree of injury the regeneration was more rapid than in the series with the greater degree of injury and the members of the series with the lesser degree of injury moulted more rapidly than the members of the series with the greater degree of injury.

During the summer of 1905 at the Indiana University Biological Station at Winona Lake, Indiana, the author tried some experiments on gammarus. The death rate was so great that the number of animals of each series that survived was only six, and those showed little difference in the per cent. of regeneration. The series with the lesser degree of injury showed a little greater per cent. of regeneration than the series with the greater degree of injury. No observations were made on the relation of the degree of injury to the moulting period. During the summer of 1907 at the same place the author tried some similar experiments on the same gammarus. The death rate was again great and the difference in the per cent. of regeneration was less than in the first experiments. The degree of injury made very little difference in the length of the moulting period.

## METHOD.

The gammarus used in these experiments were obtained from Winona Lake, Indiana, near the mouth of Cherry Creek. On July 9, 1905, about two hundred gammarus were taken from the lake near the mouth of

Cherry Creek and put in a glass jar partially filled with lake water. On July 11, sixty of these were selected for operation. The right hind leg was removed from each of thirty and the two pairs of hind legs were removed from the other thirty. Each series was put into a glass dish partially filled with lake water. The water was changed daily. At the end of eighteen days the death rate had been so great that only six individuals of each series survived. On examination it was found that some regeneration had taken place and it was thought best to kill those that survived. They were killed in eighty-five per cent. alcohol. The right hind leg of each individual was removed and measured under the microscope segment by segment. Likewise the right second leg was removed and measured. A comparison was made between the regenerated right hind leg and the normal right second leg. Also the body length was measured and its length was compared with the length of the regenerated right hind leg.

On July 8, 1907, the author took several gammarus from the lake near the mouth of Cherry Creek. On July 8, 9, and 10 the right hind leg was removed from each of twenty-six individuals and the two pairs of hind legs were removed from thirty individuals. This time the legs were mounted in glycerine. Each gammarus was placed in a separate dish. The animals were fed every five days and the water was changed daily. Two days after the moult the gammarus were killed in eighty-five per cent. alcohol. The right hind leg was removed and measured as before. The length of the regenerated leg was compared with the length of the original leg.

On July 17 several gammarus were taken from the lake in about the same place as before. They were put in separate dishes partially filled with lake water. The water was changed daily and the animals were fed every five days. One day after the moult either the right hind leg or the two pairs of hind legs were removed. The removed legs were mounted in glycerine. Two days after the second moult each animal was killed in eighty-five per cent. alcohol. The right hind leg was removed and measured as before. The length of the regenerated right hind leg was compared with the length of the original leg.

## Table I.—*Series A.*

| Catalog number. | Uninjured leg. | | | | Regenerated leg. | | | | Body length. | Regenerated leg l'n'g / Uninjured leg l'n'g | Per cent. Regeneration. | Regenerated leg l'n'g. / Body length. | Per cent. Regeneration |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seg. 1. | Seg. 2. | Seg. 3. | Total. | Seg. 1. | Seg. 2. | Seg. 3 | Total | | | | | |
| 1... | 10. | 7.4 | 9.1 | 26.5 | 10.1 | 8.1 | 8.9 | 27.1 | * | $\frac{10.1+8.1+8.9}{10.+7.4+9.1}$ | 102.26+ | ............ | .... |
| 2... | 8.1 | 6.2 | 6.5 | 20.8 | 5.3 | 3.9 | 4.5 | 13.7 | 118.1 | $\frac{5.3+3.9+4.5}{8.1+6.2+6.5}$ | 65.86+ | $\frac{13.7}{118.1}$ | 11.60+ |
| 3.. | 9.4 | 8. | 9.4 | 26.8 | 7. | 6.2 | 6. | 19.2 | 155.2 | $\frac{7+6.2+6.}{9.4+8.+9.4}$ | 71.64+ | $\frac{19.2}{155.2}$ | 12.37+ |
| 4...... | 9. | 6.4 | 8. | 23.4 | 8. | 6. | 6.4 | 20.4 | 156.5 | $\frac{8.+6.+6.4}{9.+6.4+8}$ | 87.18+ | $\frac{20.4}{156.5}$ | 13.03+ |
| 5... | 9.1 | 6.5 | 7.3 | 22.9 | 7. | 6.7 | 5.8 | 19.5 | 146.1 | $\frac{7.+6.7+5.8}{9.1+6.5+7.3}$ | 85.58+ | $\frac{19.5}{146.1}$ | 13.34+ |
| ............ | 8.7 | 5.4 | 5. | 19.1 | 6. | 5.3 | 4.1 | 15.4 | 138.6 | $\frac{6.+5.3+4.1}{8.7+5.4+5.}$ | 80.99+ | $\frac{15.4}{138.6}$ | 11.11+ |

Average 82.25

*The body was torn before the measurement was taken.
Right legs were more slender than the left legs and all of them seemed to be filled with air bubbles.

# TABLE II.—*Series B.*

| Catalog number. | Uninjured leg. | | | | Regenerated leg | | | | Body length. | Regenerated leg l'n'g / Uninjured leg l'n'g | Per cent. Regeneration. | Regenerated leg l'n'g. / Body length | Per cent. Regeneration. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seg. 1. | Seg. 2. | Seg. 3. | Total | Seg. 1. | Seg. 2. | Seg. 3. | Total. | | | | | |
| 1 | 10.5 | 8.8 | 8.6 | 27.9 | 10.1 | 9.8 | 9.5 | 29.4 | 150.9 | 10.1+9.8+9.5 / 10.5+8.8+8.6 | 105.37+ | 29.4 / 105.9 | 19.48+ |
| 2 | 10.6 | 9. | 8.8 | 28.4 | 7. | 6.5 | 6. | 19.5 | 165.2 | 7.+6.5+6 / 10.6+9.+8.8 | 65.14+ | 19.5 / 165.2 | 11.80+ |
| 3 | 10.6 | 7.9 | 8. | 26.5 | 9.1 | 7.8 | 6.8 | 23.7 | 147.8 | 9.1+7.8+6.8 / 10.6+7.9+8 | 89.43+ | 23.7 / 147.8 | 16.04+ |
| 4 | 11.8 | 8.5 | 9.1 | 29.4 | 6.9 | 6.8 | 6.8 | 20.5 | 157.9 | 6.9+6.8+6.8 / 11.8+8.5+9.1 | 69.72+ | 20.5 / 157.9 | 12.98+ |
| 5 | 9. | 6. | 7.8 | 22.8 | 7.8 | 6.9 | 6. | 20.8 | 128.3 | 7.9+6.9+6 / 9.+6+7.8 | 91.22+ | 20.8 / 128.3 | 16.24+ |
| 6 | 7.9 | 5. | 6.1 | *19. | 6. | 5.2 | 5.5 | 16.7 | 118.6 | 6.+5.2+5.5 / 7.9+5.+[illegible] | 87.89+ | 16.7 / 118.6 | 14.08+ |
| | | | | | | | | | | | Average 84.79 | | |

*The claw and first segment were broken off and lost. The length of the first segment was calculate'

**Table III.**—*Series A.*

| Catalog number. | Uninjured leg. | | | | Regenerated leg. | | | | Regenerated leg l'n'g. / Uninjured leg l'n'g | Per cent. Regeneration. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Seg. 1. | Seg. 2 | Seg. 3. | Total. | Seg. 1. | Seg. 2. | Seg. 3. | Total. | | |
| 68-A-2 | 6.9 | 5.6 | 5.4 | 17.9 | 3.8 | 2.8 | 2.8 | 9.4 | $\frac{3.8+2.8+2.8}{6.9+5.6+5.4}$ | 52.5+ |
| 68-A-3 | 7.4 | 7.2 | 6.0 | 20.6 | 4.2 | 3.6 | 3.6 | 11.4 | $\frac{4.2+3.6+3.6}{7.4+7.2+6.0}$ | 55.3+ |
| 68-A-4 | 6.4 | 5.8 | 5.6 | 17.8 | 4.2 | 4.0 | 3.2 | 11.4 | $\frac{4.2+4.0+3.2}{6.4+5.8+5.6}$ | 63.8+ |
| 68-A-6 | 5.0 | 4.8 | 4.2 | 14.0 | 2.8 | 2.4 | 2.2 | 7.4 | $\frac{2.8+2.4+2.2}{5.0+4.8+4.2}$ | 52.8+ |
| 68-A-8 | 5.2 | 5.2 | 4.8 | 15.2 | 3.6 | 3.7 | 3. | 10.3 | $\frac{3.6+3.7+3.}{5.2+5.2+4.8}$ | 67.7+ |
| 68-A-10 | 6.8 | 6.0 | 5.2 | 18.0 | 4.6 | 4.2 | 3.2 | 12.0 | $\frac{4.6+4.2+3.2}{6.8+6.0+5.2}$ | 66.6+ |
| 68-A-11 | 4.8 | 5.0 | 4.8 | 14.6 | 3.6 | 3.2 | 3. | 9.8 | $\frac{3.6+3.2+3.}{4.8+5.0+4.8}$ | 67.1+ |

Average 60.8+

TABLE IV.—Series B.

| Catalog number. | Uninjured leg | | | | Regenerated leg. | | | | Regenerated leg l'n'g. / Uninjured leg l'n'g. | Per cent. Regeneration. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Seg. 1. | Seg. 2. | Seg. 3. | Total. | Seg. 1 | Seg. 2 | Seg. 3. | Total | | |
| 68-B-3 | 6.8 | 6.6 | 6. | 19.4 | 3.2 | 3.2 | 3. | 9.4 | $\frac{3.2+3.2+3}{6.8+6.6+6}$ | 48.4+ |
| 68-B-4 | 5.2 | 5.4 | 4.8 | 15.4 | 3.2 | 2.8 | 3.2 | 9.2 | $\frac{3.2+2.8+3.2}{5.2+5.4+4.8}$ | 59.7+ |
| 68-B-5 | 5. | 5.2 | 4.8 | 15.0 | 4.2 | 3.4 | 3. | 10.6 | $\frac{4.2+3.4+3.}{5.+5.2+4.8}$ | 70.6+ |
| 68-B-7 | 5.6 | 5.4 | 5. | 16.0 | 3. | 3.2 | 3.4 | 9.6 | $\frac{3.+3.2+3.4}{5.6+5.4+5.}$ | 60. |
| 68-B-8 | 6.2 | 6. | 5.4 | 17.6 | 4. | 3.2 | 3. | 10.2 | $\frac{4.+3.2+3.}{6.2+6.+5.4}$ | 58 — |
| 68-B-10 | 5.8 | 4. | 4. | 13.8 | 3.8 | 3.6 | 3.4 | 10.8 | $\frac{3.8+3.6+3.4}{5.8+4.+4.}$ | 78.2+ |

Average 62.5+

TABLE V.—*Series A.*

| Catalog number. | Uninjured leg. | | | | Regenerated leg. | | | | Regenerated leg l'n'g. / Uninjured leg l'n'g | Per cent. Regeneration. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Seg 1 | Seg 2 | Seg 3 | Total | Seg. 1. | Seg 2 | Seg 3. | Total | | |
| 72 | 5.8 | 5.4 | 5. | 16.2 | 3.4 | 3. | 3.4 | 9.8 | $\frac{3.4+3.+3.4}{5.8+5.4+5}$ | 60.4+ |
| 98 | 5. | 4.2 | 4.2 | 13.4 | 2.8 | 2.2 | 2.2 | 8.2 | $\frac{2.8+2.2+2.2}{5.+4.2+4.2}$ | 60.4+ |
| 76 | 5.4 | 4.4 | 4 | 13.8 | 3. | 2.2 | 2.2 | 8.4 | $\frac{3.+2.2+2.2}{5.4+4.4+4}$ | 60.8+ |
| 87 | 5.2 | 4.8 | 5. | 15.0 | 3.2 | 3. | 3.2 | 9.4 | $\frac{3.2+3.+3.2}{5.2+4.8+5}$ | 62.6+ |
| 102 | 6. | 5.8 | 5.2 | 17.0 | 3.6 | 3.2 | 3.2 | 10.0 | $\frac{3.6+3.2+3.2}{6.+5.8+5.2}$ | 58.8+ |
| 109 | 5.4 | 5.2 | 5. | 15.6 | 3.2 | 3. | 3.2 | 9.4 | $\frac{3.2+3.+3.2}{5.4+5.2+5.}$ | 60.2+ |

Average 60.5+

TABLE VI.—*Series B.*

| Catalog number. | Uninjured leg. | | | | Regenerated leg. | | | | Regenerated leg l'n'g. / Uninjured leg l'n'g. | Per cent. Regeneration. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Seg. 1. | Seg. 2 | Seg. 3. | Total | Seg. 1. | Seg. 2. | Seg. 3. | Total. | | |
| 77 | 4.4 | 3.8 | 3.8 | 12. | 3.2 | 2.6 | 2.4 | 8.2 | $\frac{3.2+2.6+2.4}{4.4+3.8+3.8}$ | 68.3+ |
| 88 | 5.2 | 4.8 | 4.6 | 14.6 | 3.4 | 2.8 | 2.6 | 8.8 | $\frac{3.4+2.8+2.6}{5.2+4.8+4.6}$ | 60.2+ |
| 91 | 4.4 | 4. | 3.8 | 12.2 | 2.6 | 2.4 | 2.4 | 7.4 | $\frac{2.6+2.4+2.4}{4.4+4.+3.8}$ | 60.6+ |
| 100 | 4.6 | 4.4 | 3.4 | 12.4 | 2.2 | 2.4 | 2.2 | 6.8 | $\frac{2.2+2.4+2.2}{4.6+4.4+3.4}$ | 54.8+ |
| 103 | 5.6 | 5.8 | 5. | 16.4 | 3.4 | 2.8 | 2.6 | 8.8 | $\frac{3.4+2.8+2.6}{5.6+5.8+5}$ | 53.5+ |

Average 59.5+

TABLE VII.—*Series A.*

| Catalog number. | Date of operation. | Date of first moult. | Date of second moult. | Number of days after operation until first moult. | Number of days after firts moult until second moult. | Per cent. Regeneration. |
|---|---|---|---|---|---|---|
| 68-A-2 | July 8 | July 11 | July 27 | 3 | 16 | 52.5+ |
| 68-A-3 | July 8 | July 10 | July 28 | 2 | 18 | 55.3+ |
| 68-A-4 | Jluy 10 | July 22 | August 10 | 12 | 19 | 63.8+ |
| 68-A-6 | July 10 | July 15 | July 30 | 5 | 15 | 52.8+ |
| 68-A-8 | July 10 | July 16 | July 29 | 6 | 13 | 67.7+ |
| 68-A-10 | July 10 | July 21 | August 10 | 11 | 20 | 66.6+ |
| 68-A-11 | July 10 | July 20 | August 2 | 10 | 13 | 67.1+ |
| | | | | Average 7[illegible] | Average 16[illegible] | Average 60.8 |

## Table VIII.—*Series B.*

| Catalog number. | Date of operation. | Date of first moult. | Date of second moult. | Number of days after operation until first moult. | Number of days after firts moult until second moult. | Per cent. Regeneration. |
|---|---|---|---|---|---|---|
| 68-B-3 | July 8 | July 10 | August 2 | 2 | 23 | 48.4+ |
| 68-B-4 | July 9 | July 12 | July 30 | 3 | 18 | 59.7+ |
| 68-B-5 | July 9 | July 16 | July 28 | 7 | 12 | 70.6+ |
| 68-B-7 | July 9 | July 13 | July 25 | 4 | 12 | 60. |
| 68-B-8 | July 9 | July 18 | July 31 | 9 | 13 | 58.— |
| 68-B-10 | July 10 | July 21 | August 2 | 11 | 12 | 78.2+ |
| | | | | Average 6. | Average 15. | Average 63.5— |

## Table IX.—*Series A.*

| Catalog number. | Date of operation. | Date of Moult. | Number of days between moult and operation. | Per cent. Regeneration. |
|---|---|---|---|---|
| 72 | July 14 | July 27 | 13 | 60.4+ |
| 98 | July 26 | August 7 | 12 | 60.4+ |
| 76 | July 17 | August 1 | 12 | 60.8+ |
| 87 | July 20 | August 6 | 17 | 62.6+ |
| 102 | July 27 | August 10 | 14 | 58.8+ |
| 109 | July 30 | August 13 | 14 | 60 2+ |
| | | | Average 13⅔. | Average 60.5+ |

## Table X.—*Series B.*

| Catalog number. | Date of operation. | Date of Moult. | Number of days between moult and operation. | Per cent. Regeneration. |
|---|---|---|---|---|
| 77 | July 17 | July 31 | 14 | 68.3+ |
| 88 | July 22 | August 6 | 15 | 60.2+ |
| 91 | July 22 | August 11 | 20 | 60.6+ |
| 100 | July 26 | August 10 | 15 | 54.8+ |
| 103 | July 27 | August 11 | 15 | 53.5+ |
| | | | Average $15\frac{4}{5}$. | Average 59.5— |

**Explanation of Tables—**

From the individuals in series A the two pairs of hinds legs were removed. From the individuals in series B the right hind leg was removed. The per cent. of regeneration was obtained by dividing the length of the regenerated leg by the length of the leg with which it was compared.

The animals of tables I and II are those on which the experiments were tried in 1905. The per cent. of regeneration was also obtained by dividing the regenerated leg length by the body length.

The animals of tables III and IV are those that were kept until they had moulted a second time.

The animals of tables V and VI are those that were operated upon on the next day after the moult.

Tables VII, VIII, IX, and X give the date of operation, date of moult, the time between moults and the per cent. of regeneration.

**Discussion of results—**

Table I shows that the average per cent. of regeneration as measured by comparing the length of the regenerated right hind leg with the length of the normal right second leg in series A is 82.25. Table II shows that the per cent. of regeneration as measured by comparing the length of regenerated right hind leg with the length of normal right second leg is 84.79. This shows that the series with the lesser degree of injury has regenerated 2.54 per cent. more than the series with the greater dgree of injury. This difference is scarcely enough to take into account.

Table III shows that the average per cent. of regeneration as measured by comparing the length of the regenerated right hind leg with the length of the removed right hind leg in series A is 60.8. Table IV shows that the per cent. of regeneration as measured in the same way as series A, table III, in series B is 62.5. This shows that the series with the lesser degree of injury has regenerated 1.7 per cent. more than the series with the greater degree of injury. This difference is less than before.

Table V shows that the per cent. of regeneration as measured as above in series A is 60.5. Table VI shows that the per cent. of regeneration measured as above in series B is 59.5. This shows that the series with the greater degree of injury has regenerated 1 per cent. more than the series with the lesser degree of injury. In each case the two series compared were treated in as nearly the same way as possible with the exception of the degree of injury.

Table VII series A shows an average of 16 2-7 days between moults. Table VIII, series B, shows an average of 15 days between moults. This shows that the series with the greater degree of injury has an average of 1 2-7 days longer between moults than the series with the lesser degree of injury.

Table IX, series A, shows an average of 13 2-3 days between operation and moult, which would make 14 2-3 days between moults. Table X, series B, shows an average of 15 4-5 days between the operation and the moult, which would make a period of 16 4-5 days between moults. This shows that the series with the lesser degree of injury has an average of 1 2-15 days longer period between moults than the series with the greater degree of injury. An average of the two sets of observations shows practically no difference between the length of the moulting period of the series with the greater degree of injury and the series with the lesser degree of injury. In each case the series with the longer period between moults has the lesser per cent. of regeneration. Conclusions:

1. The degree of injury of the gammarus has no effect on the rate of regeneration in the legs of the gammarus.

2. The degree of injury in the gammarus has no effect on the length of the moulting period of the gammarus.

# The Influence of Environment on Man.

By Robert Hessler.

(Abstract.)

The paper traced in broad lines the influence of latitude as seen in the frigid, torrid, and temperate zones. Factors that bear on the matter of health and ill-health were taken up in some detail for the temperate zone.

Local State conditions were then taken up from the standpoint of the biologist and evolutionist, beginning with the primitive inhabitants, the Indians; the absence of diseases on account of their environment and customs was commented on. The white settlers who came in belonged to a race where elimination through the action of disease had been going on actively for ages and among whom the more susceptible had been killed off and were still being killed off, but today largely dependent on modifiable disease-producing conditions.

Individuals or families or strains whose history goes back to European city life may show quite a different reaction to present day environment than does that of those whose ancestry goes back to country life with little elimination on account of diseases. The early Jews who arrived in this country were almost exclusively from the cities where the disease weeding out process had been most severe; the Jews coming in today are mainly from the country districts where the air conditions are good, and when these crowd into our dirty cities many fail. Asiatics, again, coming from the highly unsanitary cities are able to thrive in our own cities, because they are the survival of the fittest, fittest to live under unsanitary surroundings.

Among the descendants of the pre-revolutionary immigrants to this country we have to consider the ancestral urban or rural life, and similar life conditions since in this country, with its attendant elimination or non-elimination. A hardy stock transferred to an isolated environment, as to the southern mountains, is to a large extent exempted from exposure to diseases and practically all the offspring may reach the re-

productive stage; when removal to the crowded city takes place elimination through disease is apt to go on actively.

Reaction to environment varies greatly, from a feeling of health to illhealth and disease. Pain is to be regarded as a warning from nature and plays an important role in the process of adaptation to environment. Some strains or individuals are wholly unadapted to city life with its manifold disease-producing conditions. Many disease-producing conditions have been eliminated from city life today, others are more active than ever, notably the impure air factor.

A study of simple country conditions, of village conditions, of town and small city conditions may shed much light on the complex city life. Much of the illhealth and disease of the large city is preventable and the lives of many can be lengthened. The erection of more hospitals, as ordinarily conducted, is not a remedy for correcting the evils of city environment; the environmental influences are themselves to be largely altered. Much depends on education and there is urgent need for an institution that will take up the study of factors operative today.

# Some Notes on the Habits of the Common Box Turtle (*Cistudo Carolina*).

Glenn Culbertson.

During the latter part of last July, while passing through an extensive tract of woodland in the so-called "Flats" or "Slashes" of Jefferson county, I noticed a very unusual number of the common box turtle in a pool of muddy water. The pool was less than ten feet in diameter and was frequented by a number of hogs as a wallow.

On removing from the pool the turtles, some of which were visible and others completely buried in the soft mud, I counted seventy-two. They were all sizes from two or three inches in length up to eight inches. The largest had the number 1867 carved on its under side, the number in all probability having been placed there during that year.

The number of these animals found in this pool is certainly remarkable. I have spent many hours in the woods and fields of Jefferson and other counties of southeastern Indiana, and have never, until on this occasion, seen more than two or three of these turtles together, or, in fact, during any one day.

The explanation of this unusually large gathering of these turtles is probably found in the intense heat of the ten days or two weeks preceding the date of their observation. Although the soil was not at all dry, the heat probably drove them to the pool from all sides. On the same day I observed two other turtles burying themselves in a muddy spot but a foot or so in diameter.

When I had returned the animals to the pool, and while observing them from a distance a number of hogs approached, and in a few moments several of the largest had each picked up a turtle and were endeavoring to crush the shells. I watched the performance with considerable interest, as I had previously supposed that forest fires were about the only enemy of these turtles. To my surprise the largest hogs, after many attempts, and with a noise as though cracking walnuts, succeeded in crushing the

shells, and surrounded by a group of smaller animals of their kind, squealing for a share, they ate the contents with evident satisfaction.

I drove the hogs away, but on revisiting the place a few hours later. I found that the hogs had returned, and that they had crushed and eaten the greater number of the smaller turtles, and some that were as much as six inches in length.

From these observations it would seem that the hog has been one of the principal enemies of this turtle, and that in recent years, since few hogs have been allowed to range the woods and fields, the box turtle has been rapidly increasing in number.

# The Peronosporales of Indiana.

Guy West Wilson.

The species of this order of fungi are all parasitic upon the higher plants and are of two types known respectively as the White Rusts and the Downy Mildews. The White Rusts (*Albugo*) are easily recognized by their milk-white, glistening sori which are produced on the leaves and stems, and even on the flowers and fruits of various weeds and a few useful plants. The Downy Mildews produce white mould-like patches upon the under surface of the leaves of various plants. To this group belongs the Downy Mildew of the grape (*Rhysotheca viticola* (B. & C.) G. W. Wilson) which is one of our most destructive fungous diseases.

Our knowledge of the Indiana species of the order is in a great degree due to the work of the late Dr. L. M. Underwood, whose "List of Cryptogams at Present Known to Inhabit the State of Indiana"* contains a list of fourteen species of three genera on twenty-seven hosts which were completely determined, besides six additional entries of hosts by generic name only. As a result of a study of the material in the herbaria of Dr. J. C. Arthur and of the author, a paper entitled "The Phycomycetes of Indiana" was prepared and presented to this Academy two years ago. This paper contained four additional species of this order, one of them being admitted on the authority of Dr. W. A. Kellerman. Since this time *Peronospora floerkeae* Kellerman has been recorded as a member of our flora.†

Within the last year the opportunity presented itself of restudying the material in the herbarium of Dr. Underwood and of verifying the determinations both of fungi and hosts. This resulted in the detection of a new host and in the reduction of three of the six partially determined ones to others already listed. Subsequent field work has supplemented the list both of fungi and hosts until now twenty-two species of six genera on forty-seven hosts are known from the state. The number of genera as compared with previous published records is doubled, the number of species has been increased a third, and the list of hosts almost doubled.

*Proc. Ind. Acad. Sci. 1893: 31-33. 1894.
†Wilson, Torreya, 6:192. 1907.

In conclusion I wish to most heartily thank those botanists who have so kindly co-operated with me in this work.

## FAMILY 1. ALBUGINACEAE.

1. ALBUGO BLITI (Biv.) Kuntze.

   On *Acnida tamariscina* (Nutt). Wood, Hamilton, 8:1907‡.

   On *Amaranthus graecezans* L., Tippecanoe, 10:1907.

   On *Amaranthus hybridus* L. (including *A. sp.* of Underwood), Johnson, Putnam, Tippecanoe 1893:31:—Madison, 8:1907.

   On *Amaranthus retroflexus* L., Johnson, 1893:31:—Hamilton. 7:1907: Madison, 8:1907; Tippecanoe, 10:1905.

   On *Amaranthus spinosus* L., Montgomery, 1893:31:—Hamilton, 7:1907.

2. ALBUGO CANDIDA (Pers.) Roussel.

   On *Brassica arvensis* (L.) B. S. P., Putnam, 8:1907.

   On *Brassica nigra* (L.) Koch, Johnson, Tippecanoe, 1893:32:—Hamilton, Putnam, 7:1907.

   On *Bursa bursa-pastoris* (L.) Britton, (*Capsella Bursa-pastoris* Moench). Montgomery, Putnam, 1893:32:—Hamilton, 7:1907; Tippecanoe, 5:1906.

   On *Cardamine bulbosa* (Torr.), Britton, Montgomery, 1893:32§.

   On *Dentaria* sp., Montgomery, 1893:32.

   On *Iodanthus pinnatifidus* (Michx.), Steud. (*Thelypodium pinnatifidum* Wats.), Tippecanoe, 6:1907. (Arthur) Herbarium Arthur.

   On *Lepidium virginicum* L., Putnam, 7:1907.

   On *Raphanus sativus* L., Johnson, Putnam, 1893:32; Hamilton, 7:1907.

   On *Roripa armoracea* (L.) A. S. Hitchcock (*Nasturtium armoracia* Fries). Putnam, 7:1897, 7:1907; Tippecanoe, 8:1894. (*W. Stewart.*) Herbarium Arthur.

   On *Roripa palustris* (L.) Bessey (*Nasturtium palustre* DC.), Hamilton, 8:1907.

   On *Sinapus alba* L., Johnson, 1893:32.

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‡Date of collection. Other references are to year and page of these proceedings, *i. e.*, 1893:31.

§ The material in the Underwood herbarium is labeled as above, but listed as *C. bulbosa purpurea*.

On *Sisymbrium officinalis* (L.) Scop., Brown, Putnam, 1893:32:—Hamilton, 7:1907.

On *Sophia pinnata* (Walt.), Britton (*Sisymbriom canescens* Nutt). Putnam, 1893:32:—Tippecanoe, 5:1905.

On *Sophia millefolium* Rydberg, Putnam, 1893:32 (as *Sisymbrium canescens* p. p.).

3. Albugo ipomoeae-panduranae (Schw.) Swing.

On *Ipomoeae hederacea* Jacq. (*I. nil.*), Putnam, Tippecanoe, 1893:32:—Hamilton, 8:1907.

On *Ipomoea pandurata* (L.) Meyer. Johnson, 1893:32:—Tippecanoe, 6:1898. (*Arthur.*) Herbarium Arthur.

4. Albugo portulacae (DC.) Kuntze.

On *Portulaca oleracea* L., Johnson, Montgomery, Putnam, Tippecanoe, 1893:32:—Hamilton, 8:1907; Madison, 8:1907.

5. Albugo tragopogonis (DC.) S. F. Gray.

On *Ambrosia artemisiaefolia* L., Putnam, 7:1907.

## FAMILY 2. PERONOSPORACEAE.

6. Basidiophora entospora Roze and Cornu.

On *Aster novae-angliae* L., Tippecanoe, 5:1907.

7. Sclerospora graminicola (Sacc.) Schröter.

On *Setaria* sp., Steuben. (*Kellerman.*) Herbarium Ohio State University.

8. Rhysotheca australis (Speg.) G. W. Wilson.

On *Sicyos angulatus* L., Johnson, 1893:32:—Tippecanoe, 9:1905.

9. Rhysotheca geranii (Peck) G. W. Wilson.

On *Geranium carolinianum* L., Putnam, Vigo, 1893:32.

10. Rhysotheca Halstedii (Farlow) G. W. Wilson.

On *Bidens connata* Mühl., Johnson, 1893:32.

On *Bidens frondosa* L., Johnson, 1893:32:—Hamilton, Madison, 8:1907; Putnam, 7:1907.

On *Erigeron annuus* L., Hamilton, 8:1907.

On *Helianthus annuus* L., Montgomery, 1893:32.

11. Rhysotheca obducens (Schröter) G. W. Wilson.

On *Impatiens aurea* Mühl. (*I. pallida* Nutt.), Tippecanoe, 1893:32.

On *Impatiens biflora* Walt. (*I. fulva* Nutt., *I. sp.* of Underwood), Putnam, 1893:32:—Marion, 5:1906.

12. **Rhysotheca viticola** (B. & C.) G. W. Wilson.

On *Vitis aestavilis* Michx., Tippecanoe, 6:1894 (*Arthur*). Herbarium Arthur; Lake, 7:1894 (*Arthur*). Herbarium Arthur.

On *Vitis cordifolia* Michx., Johnson, 1893:32:—Hamilton, Putnam. 7:1907; Tippecanoe, 9:1905.

On *Vitis labrusca* L. (including *Vitis sp. cult.* of Underwood), Crawford, Johnson, Montgomery, Putnam, 1893:32:—Hamilton, 7:1907; Madison, 8:1907.

13. **Bremia lactucae** Regel.

On *Lactuca canadensis* L., Hamilton, Putnam, 7:1907.

On *Lactuca sativa* L., In Greenhouses, Tippecanoe, 3:1903, (*Arthur*). Herbarium Arthur.

14. **Peronospora alta** Fuckel.

On *Plantago major* L., Johnson, Putnam, 1893:32:—Hamilton, 8:1907.

15. **Peronospora corydalis** de Bary.

On *Bicucula canadensis* (Goldie) Millsp. (*Dicentra canadensis* DC.), Putnam, 1893:32:—Tippecanoe, 5:1906.

On *Bicucula cucularia* (L.) Millsp. (*Dicentra cuclaria* DC.), Montgomery, 1893:32.

16. **Peronospora effusa** (Grev.) Rabenh.

On *Chenopodium album* L. (including *Chenopodium sp.* of Underwood), Johnson, Putnam, 1893:32:—Hamilton, 8:1902; Tippecanoe, 6:1894 (*Olive*).

17. **Peronospora euphorbiae** Fuckel.

On *Euphoribia humistrata* Engelm., Tippecanoe, 6:1902 (*Arthur*). Herbarium Arthur.

On *Euphorbia maculata* L., Hamilton, 8:1907; Putnam, 7:1907.

18. **Peronospora ficariae** Tul.

On *Ranunculus recurvatus* Poir (including *Ranunculus sp.* of Underwood), Montgomery, Putnam, 1893:32.

19. **Peronospora floerkeae** Kellerman.

On *Floerkea proscerpinacoides* Willd., Hamilton, 5:1906.

20. **Peronospora parasitica** (Pers.) Fries.

On *Brassica nigra* (L.) Koch., Putnam, 8:1907.

On *Raphanus sativus* L., Hamilton, 7:1907.

On *Sophia pinnata* (Walt.) Britton (*Sisymbrium canescens* Nutt.) Tippecanoe, 5:1905.

21. PERONOSPORA POLYGONI Thümen. (*P. rumicis* Aut. p. p.)
On *Polygonum scandens* L., Johnson, 1893:33:—Hamilton, 7:1907; Putnam, 8:1907.

22. PERONOSPORA POTENTILLAE de Bary.
On *Potentilla monsepalensis* L. (*P. norvegica* L.), Hamilton, 7:1907; Putnam, 8:1907.

Upper Iowa University,
Fayette, Iowa.

# The Behavior of the Chromosomes in Pinus and Thuya.

I. M. Lewis.

A more uniform interpretation prevails among botanists today concerning the reduction of chromosomes in the spore mother cells of the higher seed plants than at any time in the history of this most perplexing of all questions. The view once prevalent that the reduction is brought about by two longitudinal fissions of the chromatin has been almost entirely abandoned, and there is a growing belief which is now almost universal that a true numerical reduction takes place as proposed by Weismann several years ago, although this occurs in the first instead of the second mitosis.

The question of the occurrence of a true reducing division may be taken, therefore, as quite definitely settled. The investigations which have brought about this condition have, however, raised new questions which are almost as difficult. Chief among these questions may be mentioned: the individuality of chromosomes, the origin of chromosomes from the spirem and the manner in which the characters are distributed to the germ cells. Concerning these questions there are various conflicting views. It is quite generally accepted among cytologists, that the maternal and paternal chromatin remain in a state of complete segregation throughout the growth phase of the organism and that they become more or less completely united at the time of synapsis. The behavior of chromosomes in hybrid forms has had a great influence in bringing about this conception.

It is concerning the origin of the chromosomes from the resting neucleus and their union in synapsis that the widest difference of opinion is held. There is one group of investigators among whom Strasburger, Guignard, Allen, Overton and others are prominent who maintain that the chromosomes of each ancestry become arranged into a complete spirem previous to synapsis, that these two spirems then approach each other and apparently fuse side by side into one during the synaptic phase. Following synapsis the spirems again separate somewhat and cross segmentation takes place. The somatic chromosomes which have been so united side by side become variously oriented toward each other and thus give rise to the heterotype bivalents typical of this mitosis.

The opposite view which has been supported by Farmer and Moore, Mottier, Shaffner, Juel and others, holds that two spirems are not formed previous to synapsis, but that the spirem is formed singly and the chromosomes are arranged tandem in the spirem. The bivalent chromosomes are formed by the spirem segmenting into pieces the length of two chromosomes. These pieces have often formed loops, but this is not always the case. Some of the pieces become approximated after cross segmentation.

In the two genera investigated there are no signs of a complete spirem previous to synapsis. The chromatin content of the nucleus always exists as rather large granular chromatic lumps connected by delicate anastomosing strands of linen. The number of these lumps is quite large, much exceeding the number of somatic chromosomes typical of the species. There is, therefore, no support in these genera for the theory of the individuality of chromosomes based on the idea of prochromosomes as suggested by Rosenburg for Drosera and by Overton for Thalictrum.

The first indication that the synaptic condition is approaching is the withdrawal of the nuclear net work toward one side of the nuclear cavity. There is no change whatever in its structure or staining reaction. Some of the chromatin bodies may be seen lying together in close proximity, but this is not interpreted as an indication that they are preparing for subsequent fusion. It is likewise clear that an occasional linen thread follows for some distance the same course as one lying near it, but this does not occur with anything like the regularity figured by Allen, Cardiff and others and is regarded as occurring too irregularly to have any significance. The synaptic condition is reached while the nuclear content is still in the form of a reticulum. There is no pairing of chromomeres or of the linen threads connecting them.

The chromatin emerges from the synaptic knot in the form of a rather broad spirem or skein which frequently reveals a double nature and this is interpreted as due to a longitudinal fission. The spirem becomes quite evenly distributed throughout the cavity. It may frequently happen, however that the more regular spirem gives rise to a very irregular and somewhat lumpy reticulum before cross segmentation. Formation of the chromosomes now takes place. The chromosomes consist of two somatics, which have either become approximated together or were not separated from each other during segmentation.

The chromosomes now become arranged in the spindle plate by the action of the fibers and their distribution to the daughter nuclei takes

place. This is affected in such a way that the members of the bivalent are separated and one member passes entire to each daughter nucleus. thus bringing about a qualitative division. The retreating chromosomes undergo longitudinal fission as they pass to the poles. Having arrived at the poles, they soon break up into smaller pieces, lose entirely their identity and form a complete resting nucleus. This condition lasts but a short time when a spirem is again formed which segments into rod shaped univalent segments. These segments have been quite generally assumed to be identical with the ones which appeared at the poles of the spindle at the close of the first mitosis, but since these segments were seen to lose their identity entirely there is no basis in fact for such a supposition. If these segments are not identical with the grand daughter segments of the first mitosis then this division is not equational. The first division in both genera is qualitative and reductional; the second may be conceived either as equational or qualitative.

The investigations on which this preliminary report is based will appear later in a more complete form, together with figures illustrating the entire process of mitosis.

# The Insect Galls of Indiana.

Mel T. Cook.

During the past summer I have received a large number of species of galls from Mr. F. C. Greene, of New Albany, Indiana. This material was collected in the vicinity of Winona Lake and contained a number of well defined species, including 17 species not recorded in my "Insect Galls of Indiana."* In order to facilitate the work of future students on the flora and fauna of the state and also to give records of distribution to the more general students who may be working over the material of a greater territory, it has been considered advisable to publish descriptions of these additional species.

Mr. Greene's collection and also my own Indiana collections made some years ago contain a number of species which I am unable to determine at this time and, in fact, many which I believe to be undescribed. My studies were made primarily from the standpoint of the botanist, and as all students of these groups well know there are frequently many difficulties in making satisfactory determinations unless the insects are taken into consideration. In most cases I did not have the insects, but made my determinations from the galls. However, I hope to take up the remaining species at a later date and make satisfactory disposition of them.

A summarization of the facts presented in this paper gives the following; an addition of 17 new species of galls making a total of 82 species known to the state. An addition of 5 new genera making a total of 33 genera.* The host plants named in this list gives us two new orders, five new families and ten new genera of host plants.

*29th Annual Report of the Department of Geology and Natural Resources of Indiana, 1904, pp. 801-867.

*My Insect Galls of Indiana gave 25 Genera, but Aldrich in his Catalogue of North American Diptera (1905) transfers Cecidomyia strobiloides O. S. to the genus Rhabdophaga, Cecidomyia solidaginis Loew to the genus Dasyneura, and Trypeta solidaginis Fitch to the genus Durosta, thus bringing my list from 25 to 28 genera.

The new orders, families and genera are indicated in the following table by italics.

| *Orders.* | *Families.* | *Genera.* |
|---|---|---|
| Salicales | Salicaceae | Salix. |
| Juglandales | Juglandaceae | Hicoria. |
| | | Quercus. |
| Rosales | Rosaceae | *Spiraea.* |
| Sapindales | *Balsaminaceae* | *Impatiens.* |
| Rhamnales | Vitaceae | Vitis. |
| *Eridales* | *Vacciniaceae* | *Vaccinium.* |
| *Polmomiales* | *Labiate* | *Glecoma.* |
| | | *Monarda.* |
| | *Cichoriaceae* | *Lactuca.* |
| | *Ambrosiaceae* | *Ambrosia.* |
| Campanulales | | Vernonia. |
| | Compositae | *Erigeron.* |
| | | *Rudbeckia.* |

## HYMENOPTERA.

### CYNIPIDAE.

#### DIASTROPHUS SIMILIS Bassett.

***Diastrophus similis*—**

**Bassett, Can. Entom. Vol. XIII, No. 5, May 1881. p. 95.**

**Smith, N. J. State Bd. Agriculture 1899.**

**Ashmead, Trans. Amer. Entom. Soc. 1885. p. 294.**

**Dalla Torre, Cat. Hymen. (Cynipidae) Vol. II. 1893. p. 108.**

**Cook, Ohio Nat. Vol. III, No. 7 1903, p. 428.**

**Cook, Ohio Nat. Vol. IV, No. 6 1904. pp. 119, 120.**

This gall is spherical in shape varying from 1/8 to 3/4 inch in diameter, with one and sometimes more larval chambers in the center. The larval chamber is held in place by very coarse fibres which radiate from the center to the thin outside covering. It is a pale green color and occurs on the leaves and petioles of *Glecoma hederacea.* Sometimes two or more galls coalesce forming a compound structure. It was at first described

by Bassett from Connecticut and Long Island material in 1881. It has since been reported from New Jersey by Smith and the writer has collected it in Ohio.

ANDRICUS SINGULARIS Bassett.

*Cynips quercus-singularis*—

Bassett, Proc. Entomol. Soc. Phil. Vol. II. 1863. p. 326.

*Cynips singularis*—

Osten-Sacken, Proc. Entom. Soc. Phil. Vol. IV, 1865, p. 355.

Walsh, Amer. Ent. Vol. II. 1870. p. 184.

Osten-Sacken, 7th Rept. U. S. Geol. & Geog. Sur.-Zool. 1873 & 74. p. 567.

*Andricus singularis*—

Bassett, Amer. Nat. Vol. XVI. p. 246.

Mayr, 20 Jahresber. Comm: Oberrealsch. I. Bes. 1881. p. 28.

Ashmead, Trans. Amer. Entomol. Soc. Vol. XII. 1885, p. 295.

Gillette, 27th Ann. Agri. Rpt. of Mich. 1888, p. 469.

Gillette, Psyche Vol. V. 1889. p. 186.

Gillette, Proc. Iowa Acad. Sci. Vol. I. Pt. 2. 1890-91. pp. 110-114.

Packard, 5th Rpt. U. S. Ent. Com. (Forest Insects) 1890. p. 105.

Beutenmüller, Bul. Amer. Mus. Nat. Hist. Vol. IV. No. 1. 1892. p. 256.

Dalla Torre, Cat. Hymen. (Cynipidae) Vol. II. 1893. p. 100.

Smith, N. J. State Bd. Agriculture. 1899.

Beutenmüller, Amer. Mus. Jour. Vol. IV. No. 4. 1904. p. 15.

This gall is formed in the spring and early summer, is spherical, green and varying from ¼ to ½-inch in diameter. The larval chamber is oblong and is held in its place by radiating fibers. The outer covering is smooth and thin. It is so placed in the leaf that 2-3 project below the lower surface and 1-3 above. It very much resembles Amphibolips inanis O. S. except that it is smaller. It has been reported by Bassett from Connecticut and has since been reported from New York, New Jersey, Iowa, Michigan. The writer has also collected it in Ohio. The reports thus far indicate that it is restricted to *Quercus rubra*.

(Note.—The gall described by me in Insects galls of Indiana. 29th Rpt. of the Dept. of Geol. and Nat. Res. of Indiana 1904, p. 836, as Holcaspis centricola O. S. was an error and should have been described as A. singularis Bassett.)

AULUX TUMIDUS Bassett.

*Aulax tumidus*—

Bassett, Trans. Amer. Ent. Soc. Vol. XVII. 1890. p. 92.

Beutenmüller, Bul. Amer. Mus. Nat. Hist. Vol. IV. No. 1. 1892. p. 263.

Beutenmüller, Amer. Mus. Jour. Vol. IV. No. 4. 1904. p. 23.

*Aulax tumida*—

Dalla Torre, Cat. Hymen. (Cynipidae) Vol. II. 1893. p. 125.

This gall is a large, thick, knotty, irregular, rather ovate swelling which may be so small as to be scarcely noticeable or which may attain a length of two or three inches and a diameter of one inch. It is usually near the summit of the stalk and covered with the short flower stems of the panicle. The larvae are numerous, each enclosed in a thin transparent chamber and imbedded in the soft pithy tissue which fills the gall. It occurs on *Lactuca canadense* and possibly on other species. It was first described by Bassett who does not state the source of his material. It has since been reported from New York and the author has collected it in Ohio and Delaware. It no doubt has a very wide range and always occurs on *Lactuca.*

SOLENOZOPHERIA VACCINII Ashmead.

*Solenozopheria vaccinii*—

Ashmead, Trans. Amer. Ent. Soc. Vol. XIV. 1887. p. 149.

Dalla Torre. Cat. Hymen (Cynipidae) Vol. II. 1893. p. 57.

Beutenmüller. Amer Mus. Jour. Vol. IV. No. 4. 1904. p. 22.

A more or less irregular. usually reniform gall varying from ½ to 1 inch in length. occasionally longer and may be as much as ½-inch in diameter. Green and rather pithy in summer, becoming brown, hard and rather woody in winter. Contains a large number of larval chambers. It occurs on the stems and is restricted to one side, causing the twig to be so curved as to occupy the concave surface of the gall. This gall was first described by Ashmead from collections on Florida material of *Vaccinium corymbosum.* He also states that he received what appeared to be the same gall on *V. pennsylvanicum* from Mr. Wm. Brodie, of Toronto, Canada. It has also been reported from New York by Beutenmüller. The writer has collected it in Delaware on *V. corymbosum* and another undetermined species of *Vaccinium.* Collected in Indiana on *V. corymbosum.*

## TENTHREDINIDAE.

### PONTANIA DESMODIOIDES Walsh.

*Nematus salicis desmodioides*—

Walsh, Proc. Ent. Soc. Phil. Vol. VI. 1866. p. 257.

Norton, Trans. Amer. Ent. Soc. Vol. I. 1867. p. 211

Dalla Torre, Cat. Hymen. Vol. I. 1894. p. 259.

*Nematus inquilinus*—

Walsh, Proc. Ent. Soc. Phil. Vol. VI. 1866. p. 260.

Norton, Trans. Amer. Ent. Soc. Vol. I. 1867. p. 213.

Provancher, Can. Nat. Vol. X. 1878. p. 57.

Provancher, Faun. Ent. Can. Hymen. 1883. p. 190.

Dalla Torre. Cat. Hymen. Vol. I. 1894. p. 230.

*Pontania inquilina*—

Marlatt. Proc. Ent. Soc. Wash. Vol. III. 1895. p. 266.

*Pontania desmodioides*—

Marlatt, U. S. Dept. Agri. Div. Ent. Tech. Ser. 3. p. 40. 1896.

This gall has been recently described by Marlatt as follows: "The gall is found on *Salix humilis*. It is smooth, flattish, fleshy, sessile, yellowish green, monothalamous, semi-circular in general shape like the seed of a *Desmidium* or the quarter of an orange. It is about equally divided between the two surfaces of the leaf; no rosy cheek. Generally there is but one gall on the leaf; one leaf was seen with three upon it. Length 0.23 to 0.50 inch." It has since been reported from Massachusetts, New York, Indiana, Illinois, Missouri, and Canada.

### PONTANIA POMUM Walsh.

*Nematus salicis pomum*—

Walsh, Proc. Ent. Soc. Phil. Vol. VI. 1866. p. 255.

Norton, Trans. Amer. Ent. Soc. Vol. I. 1867. p. 216.

Walsh and Riley, Amer. Ent. Vol. II. 1869. pp. 45-49.

Riley, 9th Rept. Ins. of Mo. 1877. p. 20.

Thomas, 10th Rept. Ins. of Ills. 1881. p. 68.

Provancher. Nat. Can. Vol. XIII. 1882. p. 292.

Provancher. Can. Hymen. 1883. p. 741.

Cresson. Syn. Hymen. Amer. 1887. p. 157.

Lintner. 5th Rept. Ins. of N. Y. 1889. p. 173.

Dalla Torre. Cat. Hymen. Vol. I. 1894. p. 259.

*Nematus hospis*—

Walsh, Proc. Ent. Soc. Phil. Vol. VI. 1866. p. 261.

Norton, Trans. Amer. Ent. Soc. Vol. I. 1867. p. 218.

Dalla Torre, Cat. Hymen. Vol. I. 1894. p. 229.

*Nematus pomum*—

Beutenmüller, Bull. Amer. Mus. Nat. Hist. Vol. IV. No. 1. 1892. p. 263.

Beutenmüller, Amer. Mus. Jour. Vol. IV. No. 4. 1904. p. 23.

Cook, Ohio Nat. Vol. IV. No. 6. 1904. p. 143.

*Potania hospes*—

Marlatt, Proc. Ent. Soc. Wash. Vol. III. 1895. p. 266.

*Potania pomum*—

Marlatt, U. S. Dept. Agri. Div. Ent. (Tech. Ser.) No. 3. 1896. p. 36.

This gall has recently been described by Marlatt as follows: "The gall *S. pomum* found on *Salix cordata* and very rarely on *S. discolor*. A smooth, fleshy, globular, or slightly oval monothalamous gall, like a miniature apple, 0.30 to 0.55-inch in diameter, growing on one side of the midrib of a leaf, and extending to its edge or beyond it. The principal part of the gall projects from the under side of the leaf; very rarely it is bisected by the leaf. Color greenish yellow, sometimes with very rosy cheeks, especially the upper surface, and often with little dots." It has been reported from New York, Ohio and Illinois. Mr. Greene's specimen is on *S. discolor*(?).

## DIPTERA.

### CECIDOMYIDAE.

#### Asphondylia cospicua Osten Sacken.

*Aspondylia rudbeckiae conspicua*—

Osten Sacken, Trans. Amer. Ent. Soc. Vol. III. 1870. p. 51.

Beutenmüller, Amer. Mus. Nat. Hist. Vol. XXIII. Art. XVII. 1907, p. 387.

Beutenmüller, Bull. Amer. Mus. Nat. Hist. Vol. IV. No. 1. 1892. p. 273.

*Aspondylia conspicua*—

Aldrich, Cat. of N. A. Dipt. 1905. p. 156.

Bergenstamm & Low, Verh. Zool.-Bot. Gesell. Wien. Vol. XXVI. 1876. p. 69.

This gall was first described by Osten Sacken as follows: "They were in one case nearly round, of the size of a large apple; the other was an

aggregation of galls of various sizes, forming a large excrescence." It has been reported from New York, North Carolina and Ohio. It occurs on *Rudbeckia triloba* and *R. laciniata*. Mr. Greene's specimen was on *R. laciniata.*

CECIDOMYIA CARYAE Osten Sacken.

*Diplosis caryae*—

Osten Sacken, Stettin Entomol. Zeit. 22. 1861.

Osten Sacken, Mon. N. A. Dipt. I. 1862. p. 191.

*Cecidomyia caryae*—

Aldrich, Cat. of N. A. Dipt. 1905. p. 159.

This gall was originally described by Osten Sacken as follows: "Gall subglobular, smooth, seed-like, 0.05 to 0.1-inch in diameter, with a small nipple at the tip. In summer they are yellowish-green and their shell is soft; in winter they become brownish, and the shell, although thin, is hard and woody. They begin to grow in June. I gathered them in October, when the larva was full grown." He does not state the species of *Hicoria* on which he collected his material. Mr. Greene's Indiana material is from *H. alba.*

CECIDOMYIA CARYAECOLA Osten Sacken.

*Cecidomyia caryaecola*—

Osten Sacken, Mon. of the Diptera of N. A. Pt. I. 1862. p. 192.

Glover M. S. Notes from my Journ. Dipt. plate XI. fig. 24.

Beutenmüller, Amer. Mus. Jour. Vol. IV. No. 4. 1904. p. 27.

Smith, N. L. State Board of Agri. 1899.

Beutenmüller, Amer. Mus. Jour. Vol. IV. No. 4, 1904. p. 27.

Aldrich, Cat. of N. A. Dipt. 1905. p. 162.

These galls are pale green, elongated, onion-shaped with a pointed tip. Found through the summer in clusters on the under side of the leaves of the hickory. Frequently associated with *C. holotricha*. This gall has been recorded from New York and New Jersey, and I have collected it near Sandusky, Ohio. It is said to occur on several species of *Hicoria*. The Ohio and Indiana material were on *H. alba*.

CECIDOMYIA (?) VERNONIAE Beutenmüller.

*Cecidomyia* (?) *vernoniae*—

Beutenmüller. Amer. Mus. Nat. Hist. Vol. XXIII, Art. XVII, 1907. p. 389.

This gall was recently described by Beutenmüller as follows: "Green, sometimes tinged with red, rounded or elongated and of the texture of the stem of the plant. Inside it is soft, fleshy, and contains a single larva in an elongated narrow channel. Length about 7 to 12 mm.; width 5 to 9 mm."

"When dry the gall becomes brown and pithy inside and somewhat resembles a cherry pit. It is usually situated on the midrib of the leaf of the ironweed (*Vernonia noveboracensis*)."

Mr. Beutenmüller reports it from Black Mountains, N. C., Staten Island, N. Y., and Indiana; the last records being from the writer's material. I have since collected it in Delaware. Mr. Greene's specimen is on *Vernonia gigantia.*

### Cecidomyia salicifolia Osten Sacken.

*Cecidomyia salicifolia*—

Osten Sacken. Proc. Ent. Soc. Phil. Vol. VI. p. 220.

Aldrich, Cat. N. A. Dipt. 1905. p. 163.

This gall bears a striking resemblance to the gall of *Cecidomyia gleditschiae* O. S. The leaves are folded along the midrib, the edges uniting and the sides bulging out, thus forming a pod like structure which may be ½-inch or more in length.

This gall was first described by Osten Sacken from material collected by Wm. Couper in Quebec. He also states that he found a similar gall at Nahant on *Spiraea tomentosa* and I have received from Dr. L. M. Underwood, of Columbia University, what appears to be the same gall on *S. tomentosa.* I have collected what appears to be the same gall in Ohio on *S. salicifolia.* Mr. Greene's Indiana material is on *S. salicifolia.*

### Cecidomyia viticola Osten Sacken.

*Cecidomyia viticola*—

Osten Sacken. Stettin. Entomol. Zeit. 22. 1861.

Osten Sacken, Mon. Dipt. of N. A. Pt. I. 1862. p. 202.

Williams, 8th Rpt. Ent. Soc. Ont. 1877.

Saunders, Ins. Inj. to Fruits. 1883. p. 292.

Beutenmüller, Bul. Amer. Mus. Nat. Hist. Vol. IV. No. 1. 1892. p. 272.

Smith, N. J. State Board of Agri. 1899.

Beutenmüller, Amer. Mus. Jour. Vol. IV. No. 4. 1904. p. 32.

Aldrich, Cat. of N. A. Dipt. 1905. p. 164.

*Cecidomyia vitis lituus*—

Riley, 5th Rept. Nox. Ins. of Mo. p. 119.

Riley, Amer. Ent. Vol. II. pp. 28 & 113.

This gall may be either bright green or crimson red in color or any variation between the two. It is narrow, elongated, conical, sometimes slightly curved at tip and about 1-3 inch in length and usually on the upper surface of the leaf in great numbers. It occurs on many species of *Vitis* and has been reported from Ontario, New York, New Jersey and Missouri. The writer has also collected it in Ohio. Saunders describes it in his Insects Injurious to Fruits. So far as I know it does not attack the cultivated grapes and does not usually seriously injure the wild species. Riley reports it as attacking *V. cordifolia*, *V. riparia*, *V. labusca* and *V. vulpina*. Mr. Greene's Indiana material was on *V. bicolor*.

CECIDOMYIA IMPATIENTIS Osten Sacken.

*Cecidomyia impatientis*—

Osten Sacken, Mon. Dipt. of N. A. Pt. I. 1862. p. 204.

Osten Sacken, Amer. Ent. Vol. II. 1881. p. 63.

Glover, M. S. Notes from my Journal. Pl. XI. fig. 16.

Bentenmüller, Bul. Amer. Mus. Nat. Hist. Vol. IV. No. 1. 1892. p. 269.

Smith, N. J. State Board Agri. 1899.

Beutenmüller, Amer. Mus. Nat. Hist. Vol. IV. No. 4. 1904. p. 30.

Cook, Ohio Naturalist. Vol. IV. No. 6. 1904. p. 140.

Aldrich, Cat. N. A. Dipt. 1905. p. 162.

A spherical, green, semi-transparent, succulent swelling at the base of the flower or leaf and containing one or more larval chambers Sometimes two or more galls unite forming a compound structure. Usually scarce. Has been reported from New York, New Jersey and Ohio, and the writer has recently collected it in Delaware. Mr. Greene's material was on *Impatiens biflora* and the Delaware record is for *I. aurea*.

CECIDOMYIA MONARDAE Brodie.

*Cecidomyia monardae*—

Brodie, Biol. Rev. of Ont. I. 1894. pp. 109-111.

Aldrich, Cat. N. A. Dipt. 1905. p. 162.

Mr. Greene's specimen answers the description of Brodie's species which so far as I know has not been reported since Brodie's original de-

scription. Brodie's description is as follows: "The galls appear like swellings on the flowering branches of *Monarda fistulosa*, from 10 to 22 mm. long, usually a little curved and retaining the quadranglar form of the branch. The average of the side of the square of 20 of the largest was 3 mm., and of the branches below the galls 1.5 mm."

"This gall is usually found on plants growing in open woods, it is very rare on robust plants growing on exposed situations."

"The walls of the gall are hard and woody but thin; the interior is a soft, pith-like substance, through which the larva tunnels freely, and on which it feeds."

### CECIDOMYIA EREGERONTIS Brodie (?)

*Diplosis eregcroni*—

Brodie, Biol. Rev. of Ont. Vol. I. No. 1. p. 13.

*Cecidomyia eregerontis*—

Aldrich, Cat. of N. A. Diptera. 1905. p. 162.

This gall was described by Brodie as follows: "Variously situated from base of stem to tips of branches of flowering panicle; galls irregularly cylindrical, tapering at both ends, spindle-form, those on the branches more or less spherical; from 1 to 15 galls on a plant, seldom more than 10: found usually on diminutive plants such as grow on wet, sandy places or on high dry banks."

"As yet I have not found these galls on robust plants."

"The galls appear like swellings of the stem or branches, uniform in color with the plant, the surface with feint longitudinal lines, slightly elevated ridges and ragged transverse elevations, resembling leaf scars."

So far as I am able to determine this gall has not been reported since the original description, but during the past summer I collected what appears to be the same gall at Lewes, Delaware. All collections to date have been on *Erigeron canadense*.

## TRYPETIDAE.

### OEDASPIS GIBBA Loew.

*Trypeta gibba*—

Osten Sacken, Psyche. Vol. III. No. 72. 1880. p. 53

*Oedaspis gibba*—

Loew. Mon. of N. A. Dipt. Vol. III. p. 260.

Aldrich. Cat. of the N. A. Dipt. 1905. p. 606.

The determination of this gall is uncertain, but it is probably Osten Sacken's *T. gibba*, which was described from material collected by Mr. J. Boll, Dallas, Texas, on *Ambrosia sp.* Osten Sacken's description is very short and as follows: "The gall is an oblong swelling of the stem, probably terminal." Mr. Greene's Indiana specimen was on *A. trifida*.

## HEMIPTERIA.

### APHIDAE.

PHYLLOXERA DEPLANATA Pergande.

*Phylloxera deplanata*—

Pergande, North American Phylloxerinae. 1904. p. 205.

This gall has been reported from the D. C. by Pergande, who states that it is very similar to *P. semen* Walsh. He describes it as follows: "The leaves of some of the smaller trees are often literally covered with the galls of *deplanata* which then produce a sickly, yellowish and crumpled appearance thereof. By the end of June the galls are deserted, brown and dry, or else have completely decayed, leaving innumerable holes in the affected leaves, seriously affecting the health of the tree. When but few days old (first week in May) these galls resemble minute yellow specks."

"The transverse diameter of the mature galls varies from 1 to 5 mm.; height about 1 mm.: walls rather thin above and beneath and semi-transparent. Upper surface projecting but little above the plane of the leaf, convex, usually with a shallow fovea: frequently not central and occasionally with a slight central elevation. Under side more strongly convex, sometimes almost conical, the nipple usually more or less flattened and generally leaning to one side, as if pressed down when young; with the orifice usually oval, though sometimes more or less rounded, and which before maturity is perfectly closed and densely fringed with short pale hairs. Color above either reddish with depression yellowish, or almost entirely greenish-yellow; below purplish, or dull greenish-yellow. Many of the galls are conjoint, i. e., contains from 2 to 6 or more stem mothers, together with a large number of eggs and sexual individuals, the cavity being completely crowded."

Pergande reports this gall on *Hicoria tomentosa*. Mr. Greene's speci men was on *H. alba*.

# A Probable Origin of the Small Mounds of the Lower Mississippi and Texas Coast.

Albert B. Reagan.

Noting several articles "On the Origin of the Small Mounds of the Lower Mississippi and Texas," in Science Vol. XXIII (Mr. P. J. Farnsworth, pp. 583-4; A. C. Veatch, p. 35; Irving H. Wentworth, p. 819), leads me to make a few suggestions on the subject. In the region mentioned these mounds are very numerous, too numerous, it seems, to be Indian mounds, except the class of mounds mentioned by Mr. Irving H. Wentworth.

The mounds mentioned by Mr. Wentworth are, no doubt, of Indian origin. While with the Apache Indians some years ago, the writer saw several mounds of this type constructed. All these were erected not as places for sacrifice or any ceremonies of that sort, but as places for cooking the tuber-root of the *Agave americana*. In this cooking process, a shallow pit is first dug and lined with cobble-stones. A fire is then built in it and kept burning till the rocks are at white heat. Wet twigs (or grass) are then placed in a thick layer over the live coals and rocks. On these the Agave tubers, a wagon load or more, are quickly piled, and over these, after they have been covered with twigs or grass, a thick layer of cobble-stones are piled. All then is covered with wood, which is ignited and kept burning for about twelve hours, while the Indians dance around it. When the rocks are sufficiently cool, after the fire has been let die down, the top is removed and the cooked tubers taken out of this peculiar oven, packed in baskets, and taken to the distant "tepees," leaving the rockpile with an elliptical, practically flat top. Probably the mounds mentioned above were constructed for the same or for similar purposes.

Concerning the other mounds of the region, may they not be due to mudlump formation in a former geological epoch?

In an article on "The Exceptional Nature and Genesis of the Mississippi Delta," E. W. Hilgard states (Science, Vol. XXIV, pp. 861-866) that "mudlumps are now being upheaved in the channel of the lower Missis-

sippi," that "mudlump formation is at present the normal mode of progression of the visible delta into the gulf, the principal mudlumps rising immediately inside the bar, where the current excavates the river bed so as to relieve the superincumbent pressure." As to the origin of these mudlumps, Prof. Hilgard further states in substance (loc. cit.) that "in the Mississippi delta region there is an impervious blue clay bottom reaching out into the gulf for about twenty-eight miles beyond the present mouths of the river," that "superimposed on this is a semi-fluid blue clay stratum," and that "over this in the swamp-delta areas are deposited sandy bar material much faster than the former can escape to seaward under pressure. Consequently, wherever the river removes the superincumbent sandy, gravelly deposits, the pressure on the areas adjacent forces the semi-fluid clay to the surface in the form of mudlumps. Escaping gases also seem to aid in this mudlump formation."

Now the mounds of the lower Mississippi-Texas region are not likely identical with those of the delta proper in formation; but may they not have been made in a similar manner; that is, on the principle of "creeps"? If on an impervious bottom at the time the region in question was being formed, there was a semi-fluid layer reaching any distance inland, as the shore line advanced or receded, and this was being covered with another layer faster than it could creep seaward, whether the superficial layer was brought thereby wind or water, mudlumps would certainly have been pushed up in all the spots where the latter layer was thin or wanting. These, when dried, would become mounds.

# Some Peculiarities in the Valley Erosion of Big Creek and Tributaries.

Glenn Culbertson.

Big creek and tributaries in Jefferson county, Indiana, present some interesting features in their erosive work. The most striking of these, presented by a map of the stream and its affluents are, on the one hand, their almost uniform flow in a westerly direction, or, on the other hand, in a course almost at right angles with those flowing westward.

These characters are clearly shown in the northerly courses of Lewis and Little creeks, while their tributaries flow in a westerly direction. The same is true of Big creek and its other tributaries, as may be seen in the central and northern parts of the map. Clifty creek, a smaller stream emptying into the Ohio just below Madison, has the same peculiarities, as has also the upper portion of the West Fork of Indian Kentucky creek. In these cases the main stream flows south, while the tributaries enter from the east and northeast.

Another interesting feature so noticeable in certain parts of Big creek and its larger tributaries, where the flow is either northerly or southerly, is their remarkably meandering courses. We have been taught that meanders have been found almost exclusively in streams of gentle slope and with banks of alluvial soil. Both of these characteristics are entirely wanting in the valleys here referred to. In the case of several of the meanders the stream after flowing from one to two miles around a curve, returns to within a very short distance of the starting point. The banks of the stream, as well as the sides of the valley, where the meanders are prominent, are almost perpendicular cliffs on the convex side. These cliffs reach the height of 100 to 150 feet in the lower portions of the stream. The concave side of the meanders have gentle slopes from one-fourth to one-half a mile in length.

The peculiarities in the valley erosion of these streams is largely due to the structure of the rocks. The rock strata of this region dip gently towards the west and southwest. The amount of this dip in the more

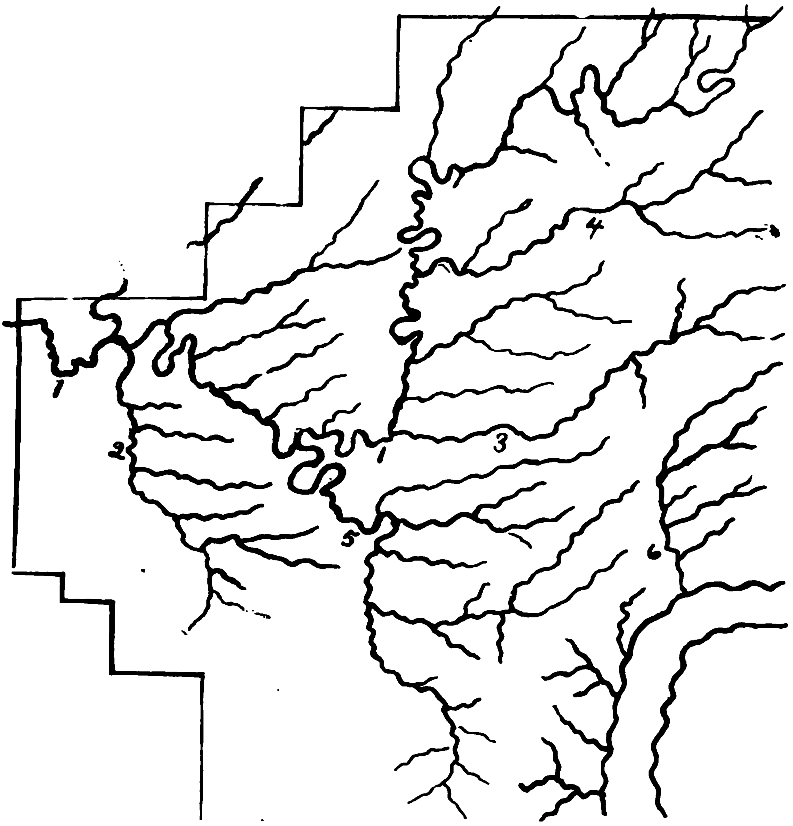
eastern parts of the county is not more than ten or twelve feet to the mile, but it increases to fifteen feet or more in the western part of the county.

The streams flowing into the Ohio directly have had to erode their valleys through the very resistant upper Hudson, Clinton and Niagara limestones. Consequently their courses are short and gradients very steep. The Wabash-Ohio divide in this part of Jefferson county is in places but one or two miles from the Ohio river, and at a comparatively short distance from the outcropping edges of the resistant limestone formations mentioned above.

Big creek and tributaries have not yet succeeded in lowering their beds to these resistant rocks, except in a very few places. Their erosive work has been in the softer corniferous limestones and New Albany black shale of the Devonian formations. The stream beds, in general, follow the dip of the rocks. In places the bed of the stream is upon the same layer of rock for long distances. Excellent examples of this may be found in the bed of Harbert's creek, between Volga and Smyrna church, as well as along parts of Middle Fork and Big creek. The dip of the rock strata has had much to do with the long, gently sloping streams flowing westward.

The tributaries that flow in an easterly direction and against the dip are very short and their gradients very high. In many of them the water pours into the main valleys over falls located but a few hundred feet from the main stream. In one case an underground stream pours forth from the face of a cliff into the principal stream. The easterly flowing tributaries eroding their beds largely or entirely in the black shale have cut somewhat longer courses than those in the limestone, but in no case do they even approximate the length of the westward flowing tributaries.

The meanders of these streams are in all probability a consequence of the variable resistance of the rocks followed by maximum erosion on the convex side of streams. They are probably consequent on the slope of the original land surface, although they may have been somewhat modified by the thin mantle left by the glaciers.




1.1.1. Big Creek.
2. Lewis Creek.
3. Harbart's Creek.
4. Middle Fork.
5. Little Creek.
6. Clifty Creek.

# Electrolytic Production of Selenic Acid from Lead Selenate.

F. C. Mathers.

Mentzer* has shown that the electrolysis of a solution of copper selenate results in the deposition of metallic copper upon the cathode and the formation of selenic acid in the solution. To obtain pure selenic acid the copper selenate must first be carefully purified by recrystallizing before electrolysis. In the experiments that are described in this paper, lead selenate was used as the salt to be electrolysed on account of the ease with which it could be prepared and purified.

Selenic acid was first prepared by oxidizing selenium dioxide in a nitric acid solution with potassium permanganate. After the precipitate of manganese dioxide had been removed by filtration, the selenic acid in the filtrate was precipitated as lead selenate by the addition of lead nitrate. Lead selenate is very insoluble in water and so can be filtered and easily washed free from the other salts in the solution.

For electrolysis, the lead selenate was placed in a platinum dish that was filled with water. The platinum dish was used as the cathode and a platinum wire coil was used as the anode. The resistance of the solution was very high at first, but it rapidly dropped as the electrolysis proceeded and the free selenic acid was formed.

To determine the amount of selenic acid that was formed during an experiment, the electrolyte was filtered and the acid in the filtrate was titrated with standard sodium hydroxide solution.

The current yield was best with low current density at the cathode, hot solution, and a large quantity of lead selenate upon the cathode, and decreased by the addition of powdered lead to the lead selenate. An increase in the volume of the solution or the use of a mercury cathode were without effect. The current yields were quite low—the maximum being about 12%.

*Mentzer, Compt. Rend., 127, 54 (1898).

The per cent. yield of selenic acid from the lead selenate was best with room temperature, thin layers of lead selenate upon the cathode, and occasional stirring. 0.3 gm. of lead selenate when electrolysed with a current density of 0.3 amperes per sq. dec. gave a yield of 95.4% of the theoretical value. Under the same conditions 3 gms. of lead selenate gave a yield of 78.3%.

University of Indiana, Nov., 1907.

# Result of Heating a Mixture of Ammonium Nitrate and Manganese Dioxide.

James H. Ransom.

Practically all the work on catalysis, in which the oxides of the metals were the catalytic agents, has been undertaken with those substances which on heating decompose with the evolution of oxygen. It has been thought by some of those who have given the subject careful investigation that, in the case of manganese dioxide, at least, the reaction is one of alternate oxidation and reduction of the catalytic agent. The arguments are not conclusive, however, so that the question whether the manganese dioxide acts as a simple contact agent or takes a chemical part in the reaction remains unanswered.

It occurred to the writer to try the effect of catalytic agents on substances which, on heating, decompose without the formation of oxygen. It was thought that if the catalytic agent acted simply as a contact agent the temperature of decomposition would be lowered but the products would be the same as when the substance was heated alone; but if the action were chemical the products would be different, perhaps more or less oxidized than when the substance was heated by itself. It was recognized, however, that if the action followed the latter supposition it would not of necessity demonstrate that all so-called cases of catalysis were chemical. Among the substances easily available for such an experiment is ammonium nitrate, which, as is well known, decomposes quite smoothly into nitrous oxide and water. The temperature of decomposition is 205°.

At my suggestion, therefore, Mr. O. C. Haworth, who was then studying the effect of various catalytic agents, undertook the preliminary investigation of the effect of heating ammonium nitrate in the presence of different oxides, among them being manganese dioxide. He established the facts that the decomposition takes place at a lower temperature than when the nitrate is heated alone; that little if any oxygen or nitrous oxide is produced; that the gas evolved is nitrogen.

On consulting the literature it was found that in 1877 Gatehouse published a short note in the Chemical News giving the results of an experiment on heating a mixture of these substances. He observed that the gas was nitrogen, and from its volume he developed an equation to explain the reaction. According to him each molecule of the oxide reacts with four molecules of the nitrate; producing six atoms of nitrogen and a molecule of manganese nitrate. The presence of the last substance he does not seem to have confirmed; and as the temperature to which he heated the mixture was above that at which manganese nitrate decomposes it appeared doubtful that the final products were as he thought. The work begun by Mr. Haworth has been continued by the writer and the nature of the reaction made more nearly complete.

In our earlier experiments some difficulties were encountered and some facts observed which modified the procedure in the later work. First, it was found most difficult so to regulate the temperature that the reaction would go smoothly and in one direction. The action would proceed at about 200° until nearly one-half of the gas had been evolved, and then suddenly without apparent cause the thermometer would suddenly mount to 300° or more and brown gases be evolved in such quantities that the stopper and connections would be forced out with explosive violence. It was thought at first that manganese nitrate was being formed in the earlier stage of the reaction and later was decomposing with evolution of heat; but experiments with this substance showed that it decomposed in a regular manner between 130° and 185°. But by heating for a time to 210°-220° and then cooling to 170° as the action proceeded it was found possible to regulate the decomposition and get consistent results.

It was also noted that after extracting the residue to determine the amount of soluble material the aqueous solution was very strongly acid with what appeared to be a nitrogen acid. The residue left on evaporation consisted of unchanged ammonium nitrate, and at times of a trace of a manganese compound.

In the succeeding experiments the apparatus was so modified that the gases could be passed through water to absorb the acid, and then collected in a large gas burette made with litre cylinders and filled with dilute alkali. About equal weights of ammonium nitrate and manganese dioxide were placed in a distilling flask connected with the acid absorbing bottle and the air in the apparatus replaced with nitrogen. The mixture was heated to 170° and then connected to the gas burette. Afterwards the

temperature was raised to between 220° and 230° and maintained there until the gas was about one-half evolved. The temperature was then lowered to 170° and kept there until the action was nearly complete, when it was again raised to 230° as long as a gas was being evolved. Finally it was cooled to 170° and the burette disconnected. Any oxygen in the burette was absorbed by pyrogallate (usually a small amount) and the nitrogen measured. Nitrogen was passed through the generator to sweep any acid vapors into the water, and the amount of acid determined by titrating against standard alkali. The residue was extracted several times with boiling water and the water evaporated in a platinum basin. The small amount of solid found on evaporation consisted mostly of unchanged ammonium nitrate.

In three closely agreeing experiments carried out as described the following figures were obtained:

1. 2.0079 gms. ammonium nitrate gave 500.5 cc. (corr.) (=0.6286 gms.) free nitrogen, and 0.7352 gms. acid (calculated as nitric).

2. 2.8955 gms. ammonium nitrate gave 635.6 cc. (corr.) (=0.7983 gms.) free nitrogen and 0.9908 gms. acid.

3. 3.8527 gms. ammonium nitrate gave 820 cc. (corr.) (=1.025 gms.) free nitrogen and 1.1000 gms. acid.

In these experiments the average ratio of free nitrogen to acid is 1:1.15. This ratio approaches very nearly to that for two molecules of nitrogen to one of the acid, viz., 1:1.125. The equation which best corresponds to this ratio is as follows:

$$5\ NH_4NO_3 = 2HNO_3 + 4N_2 + 9H_2O.$$

Reiset and Mellon have shown (Journ. fur Practische Chemie, 29-365) that when ammonium nitrate is mixed with platinum sponge and heated, decomposition begins at 160° and that the products are nitrogen and nitric acid. The equation by which they express the reaction is identical with that given above. It is unlikely that the platinum enters into the reaction, though it is stated that an insoluble platinum compound is produced. I have not been able to confirm this latter statement. If the platinum does not enter into the reaction, but acts as a true contact agent, then there seems no reason for believing that the manganese dioxide, in this reaction at least, acts in a chemical way.

It is possible that an intermediate product containing manganese may be isolated; and this will be the object of further research.

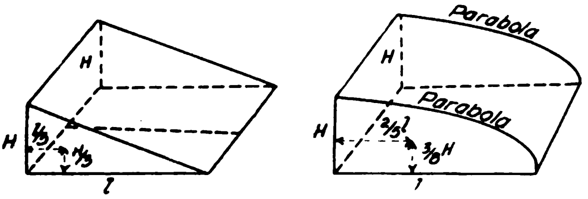
# The Mathematics of Haul.

H. O. Garman.

Haul or the average distance earth is moved when taken from excavation and placed in embankment has been the source of much discussion at different times for many years. For a review of the literature on the subject, "Overhaul," the writer will call attention to the "Proceedings of the American Railway Engineering and Maintenance of Way Association," for 1906, vol. 7, pages 357 to 428. Among the contributors to the subject will be found Italians, French and Germans, but it seemed to excite more interest among our American engineers.

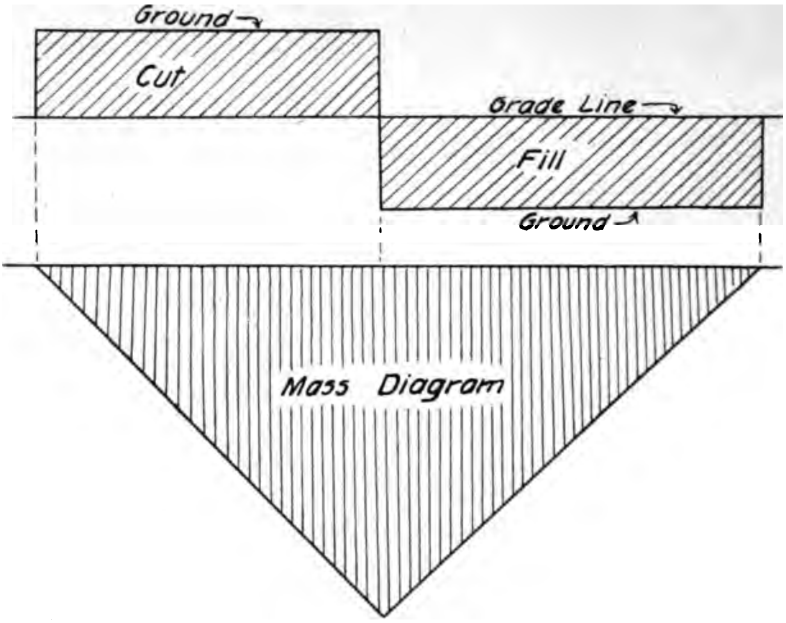
The methematics of haul deals, of course, with the methods of computing haul and overhaul, but it is the purpose here to discuss more particularly the means for locating the center of mass. These centers of mass may be located by any one of four methods, two algebraic and two graphical. All four methods for locating the center of mass fail completely for the volumes adjoining the grade point unless several extra intermediate sections are taken.

In all the calculations a close rapid approximation was used at these points

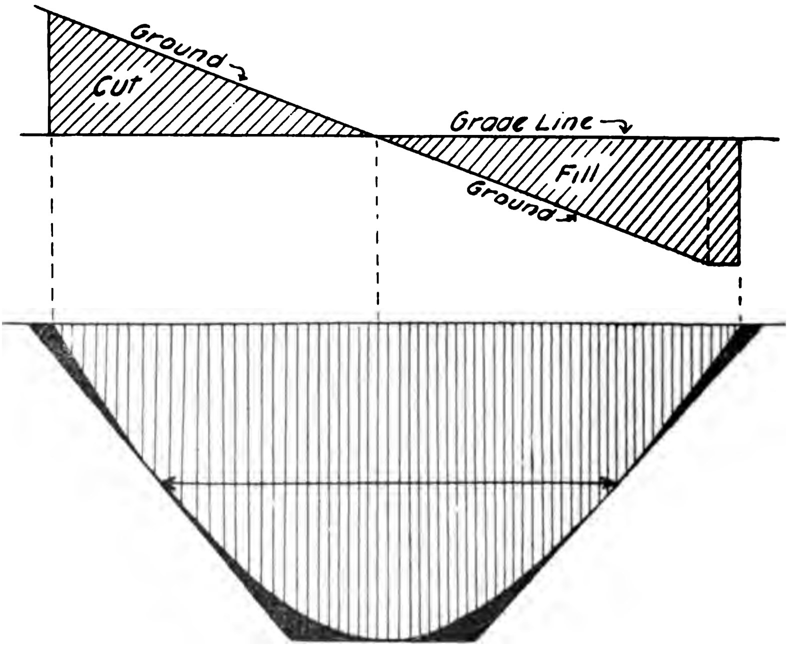



When the ground was a plane surface, the volume next the grade point was assumed at least a wedge, and the center of gravity then taken $\frac{1}{3}$ the length of the wedge from its base. When the ground was a parabola in longitudinal section, the center of gravity was taken $\frac{2}{5}$ of the length between section and grade point from the section.

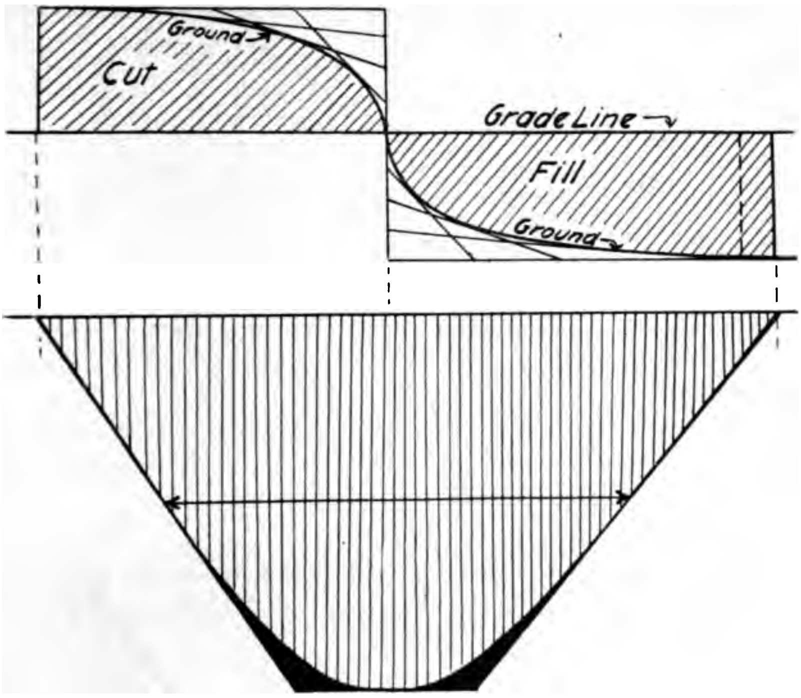
The four methods of computation were carried on under the conditions of the three general types of profile, i. e.:




Case I, all four methods of computing haul agree perfectly.




Case II. Under this condition the four methods of computing haul give their widest variance.




The above figure is Case III, and shows the ground a porabola in longitudinal section. This case most nearly coincides with the actual conditions, for haul, of any of the three cases, and any variance discovered here in the results of the four methods are about what would occur in actual practice, while those discovered under Case II are limiting values.

It being the object of the writer to discover the greatest variance that could occur, thus obtaining limiting values, most of the computations were under Case II, with a few test investigations under Case III, to obtain values that would be encountered more often in practice.

Method No. 1 depends upon the general form that the center of gravity of individual prismoids is located a distance from the mid-section toward the larger section a distance

$$\bar{X} = \frac{1}{6}\,\frac{A - A'}{A - A'} \text{ and Haul} = \frac{\Sigma\text{Moments}}{\Sigma\text{Volumes}}.$$

For all practical purposes it is exact.

Method No. 2 depends upon the general form that the center of gravity of each individual prismoid is located in from one end a distance equal to

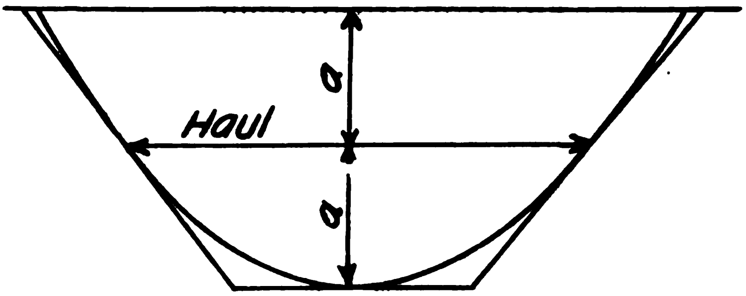
$$\bar{X}_{A'} = l \frac{A}{A + A'};$$

That is to say. it is located inversely proportional to the end areas, and

$$\text{Haul} = \frac{\Sigma\text{Moments}}{\Sigma\text{Volumes.}}$$

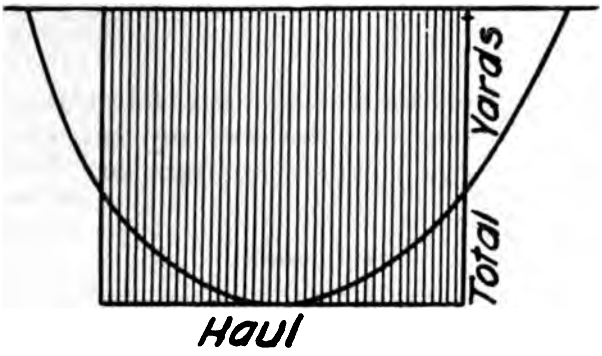
It gives results always in favor of the contractor and on very short hauls is rarely in error to exceed say 3.0 per cent. and on long hauls rarely if every exceeds 0.5 per cent.

Method No. 3 depends upon the general proposition that the position of half mass point is approximately the position of the center of mass and graphically looks like figure below.




Haul equals the mean length of the two sides of the given tropezoid and the pay haul equals the aera of the tropezoid. This method gives results always in favor of the contractor and on very short hauls is rarely in error to exceed say 4.0 per cent., and on long hauls rarely in error to exceed say 6.0 per cent.

Method No. 4, the last one treated in this report, depends for its results upon the area of the mass diagram.




The pay haul is equal to the area of the rectangle which has for its base the haul, and its altitude the total yardage or maximum ordinate, the product of the two being also the area of the mass diagram.

If the points are connected by a curved line it will give practically the true result, but if the points of the diagram are connected by straight lines as is recommended by most engineers, and as was done here, it gives values always against the contractor; on short haul being in error as high as 6 per cent., and on long haul about 1.0 per cent.

**Final summary in tabular form:**

| | Method. | | Max. Error in %. | |
|---|---|---|---|---|
| Number. | General Form. | Center of Gravity of Individual Prismoid. | Short Haul. | Long Haul. |
| No. 1. | $\text{Haul} = \frac{\Sigma M}{\Sigma V}$ | $X = \frac{1}{6}\frac{A-A'}{A+A'}$ | Correct (Practically). | Correct (Practically). |
| No. 2. | $\text{Haul} = \frac{\Sigma M}{\Sigma V}$ | $X_A = 1\frac{A}{A+A'}$ | + 3 | + 0.5 |
| No. 3. | Haul = Length of chord through middle of Maximum ordinate. | .................. | + 4 | + 6 |
| No. 4. | $\text{Haul} = \frac{\text{Total Area Diagram}}{\text{Total Yardage}}$ | .................. | − 6 | − 1 |

# Fauna of the Florena Shale of the Grand Summit Section of Kansas, and Remarks on the Development of Derbya Multistriata Meek and Hayden.

F. C. Greene.

The Grand Summit section of Cowley county, Kansas, has been famous as one of the classic collecting grounds of Kansas and many large collections have been made there. It could probably be classed as Permo-Carboniferous, very near the base of the Permian. The region was first studied by Broadhead in 1882 and the account published in 1883 or 1884. He says, "We now come to speak of the 'Permian' or limestones of the 'Flint Hills,' reaching, in Elk, Greenwood and the eastern half of Butler and Cowley counties, from 1185 to 1700 feet above the sea, including about 500 feet thickness."*

Only the top part of Broadhead's section concerns us. Numbering from top down, it is as follows:†

1. 134 feet, including beds of impure drab limestone, shaly and crumbling, with occasional shale beds, with red shales 30 feet from bottom.
2. 5 feet of bluish-drab or drab limestone containing many good characteristic fossils, including Eumicrotis hawni, Myalina perattenuata, Aviculopecten occidentalis, etc. (This bed is persistent wherever its associated strata are found.)
3. 10 feet of shales, the lower red.
4. 10 feet of rough limestone.
5. 27 feet of shales with thin shaly limestone beds.
6. 4 feet of flag-like limestone; a good building stone.
7. 8 feet of shelly buff magnesian limestone.
8. 4 feet of shaly Fusulina limestone.
9. 4 feet of cherty limestone; abound in Fusulina cylindrica, the fossils often appearing in relief; the chert of deep blue.

*Trans. St. Louis Acad. Sci., Vol. IV., Pt. 3, pages 486-487.
†Loc. Cit.

10. 18 feet limestone and shales abounding in Fusulina cylindrica.

11. 2 feet drab magnesian limestone.

12. 28 feet shaly sandstone.

He considered all above number twelve of this section as Permian which would make the base of the Permian about the horizon of the Emporia limestone of the recent geologists.

"Mr. George I. Adams has also described in a somewhat general way the section along the line of railway through Moline, Grenola, Cambridge, and Winfield."‖

In 1896 Prof. Prosser hastily examined this section. He determined number 27 of this section to be the lower part of the Strong limestone. The Strong or Wreford is now supposed to be the base of the Permian.

In the field season of 1904 Prof. Beede made a detailed section at Grand Summit as follows:§

| | | | | |
|---|---|---|---|---|
| 29. | Shales, blue with calcereous sheets and millions of fossils | 15 feet | 0 | inches |
| 28. | Limestone, blue clayey | 1 " | 0 | " |
| 27. | Shales, blue, yellow above | 5 " | 0 | " |
| 26. | Shales and shaly limestone | 5 " | 0 | " |
| 25. | Limestone, somewhat massive, weathering light | 8+ " | 0 | " |
| 24. | Shales, calcareous, and impure limestone | 7 " | 0 | " |
| 23. | Shales, clayey, with calcareous layer; very fossiliferous | 7+ " | 0 | " |
| 22. | Limestone, clayey, nodular, and clay shales. Some fossils | 3 " | 0 | " |
| 21. | Shales, yellow and blue with calcareous lenses, sea urchins | 5 " | 0 | " |
| 20. | Covered, five feet to | 8 " | 0 | " |
| 19. | Shales, red | 5 " | 0 | " |
| 18. | Shales, blue | 1 " | 0 | " |
| 17. | Limestone, blue, massive | 1 " | 0 | " |
| 16. | Shales, yellow and red (foot of limestone near base) | 10 " | 0 | " |
| 15. | Limestone, massive in one layer | 3 " | 0 | " |
| 14. | Shales, yellowish, calcareous | 1 " | 4 | " |
| 13. | Limestones, shaly | 1 " | 0 | " |

‖Prosser: "The Permian and Upper Carboniferous of Southern Kansas." Kan. Univ. Quar., Vol. VI, No. 4, 1897. Series A.

§Beede and Sellards, Stratigraphy of the Eastern Outcrop of the Kansas Permian. The American Geologist, Vol. XXXVI, August, 1905, pages 83-111.

| | | |
|---|---|---|
| 12. | Shales | 0 feet 4 inches |
| 11. | Limestones, two thin ones | 0 " 4 " |
| 10. | Shales | 0 " 6 " |
| 9. | Limestone, buff to brownish, large Fusulinas and chert in the lower part | 6 " 0 " |
| 8. | Shales, clayey | 1 " 9 " |
| 7. | Limestone, shaley to massive | 3 " 9 " |
| 6. | Shales, yellowish | 3 " 3 " |
| 5. | Limestones, thin, with shale partings | 3 " 0 " |
| 4. | Limestone, massive, in two layers | 3 " 4 " |
| 3. | Shales, yellowish, with calcareous layers rich in fossils | 9 " 0 " |
| 2. | Limestone, dark colored, in thin layers, full of pelecypods | 4 " 0 " |
| 1. | Shales, red and blue, in creek north of the cut, east of the trestle over the small creek | 11 " 0 " |
| | Total | 132 feet 7 inches |

Numbers 24 to 29 inclusive, are of the Neosho member of the Garrison formation, 23 represents the Florena shale, number 22, the Cottonwood limestone,¶ 10 to 21, inclusive, the Eskridge shales, 7 to 9, the Neva limestone and from 6 down to water-level, the Elmdale formation.

The collections upon which this paper is based were made in the summers of '04 and '05 by Prof. Beede and were taken from number 23 of the foregoing section, that is, the Florena shale.

The lists of this fauna which have been published up to the present time include about thirty-nine species. In Beede's Grand Summit collection we find 74 species. In the following list, the numbers given may be taken as representative of the fauna in the southern extension of the formation. The following are found to be the characteristic species:

| | | |
|---|---|---|
| 1. | Fusulina sp. | 800 |
| 2. | Crania cf. modesta | 67 |
| 3. | Seminula argentia | 44 |
| 4. | Productus semireticulatus | 39 |
| 5. | Productus nebrascensis | 84 |
| 6. | Chonetes granulifera | 208 |
| 7. | Derbya crassa | 79 |

¶ This statement is based on the field work of Prof. J. A. Yates in 1905.

| | | |
|---|---|---|
| 8. | Meekella striaticostata | 31 |
| 9. | Rhombopora sp. | 30 |
| 10. | Thamniscus sp. | 30 |
| 11. | Bairdia beedei | 100 |
| 12. | Bairdia beedei abrupta | 25 |
| 13. | Pteria sulcata | 128 |
| 14. | Nuculana bellistriata attenuata | 28 |
| 15. | Aviculopecten occidentalis | 40 |
| 16. | Pelecypod sp. | 200 |
| 17. | Bulimorpha chrysalis | 25 |
| 18. | Bellerophon sp. | 39 |
| 19, 20. | Gastropod, two small species | 500 |

This list comprises one species of Foraminifera, seven of Brachiopoda, two Bryozoa, two ostracods, four pelecypods, and four gastropods.

The *Fusulina* can not be said to be characteristic of the formation as a whole as it is very rare farther north. The brachiopods, as a general rule are somewhat larger than normal.

One of the most interesting species in the collection is *Derbya multistriata* Meek and Hayden. We find the first account of this species by Meek, under the name of *Orthisina umbraculum* (?) Schlotheim. He describes it as follows:

"*Orthisina umbraculum* (?) Schlot. sp. Petrefact. 1, p. 256, et 2, p. 67. We find in Kansas ranging from 16 to 19 of the foregoing section, many specimens of a large species of *Orthisina*, having almost the form and other characters of *O. umbraculum*, excepting that the striae appear to be more numerous. According to Koninck that species has about 108 striae on each valve, while on our Kansas specimens, we count from 160 to 200; consequently we suspect it to be a distinct but closely allied species. If so we would propose to designate it by the name of *O. multistriatum*. We find it at Fort Riley and at several localities between there and Blue river, also in the same position on Cottonwood creek."**

This species is not very abundant in the Florena shale, but in the shale bed just beneath the Wreford limestone, that is, in a horizon higher than this, it reaches its maximum development and becomes one of the predominating species of that fauna. Its characters are a high cardinal area, and a hinge line shorter than the greatest width of the shell. These char

**Proc. Acad. Nat. Sci. Phil., 1859, p. 26.

acters hold throughout the life history of an individual. Prosser was the first to refer this shell to *Derbya*.††

On referring to de Koninck's figure of his *Orthis umbraculum* Schlotheim|| the striking similarity will at once be apparent and by comparing this figure and description with that of Bronn,§§ of the Eiffel Devonian (apparently after examining the types), the difference between the typical *O. umbraculum* and de Koninck's specimen, and the similarity of the latter with the American species at once becomes apparent. Koninck's description gives his species 108-109 striae and if this is true, it is hardly identical with the American species as this (and de Koninck's figure) give 160 to 200 on a specimen of the same size. As to the question of the name of the American species, it is distinct from *O. umbraculum* and Meek's term will take precedence for the American form. If they are identical, as seems probable, it will also apply to de Koninck's shell.

On comparison of typical specimens of this shell with the description and figures of Hall and Clarke's *Derbya cymbula* it will be seen that they are all identical. This duplication is due to a habit of Mr. Meek's of describing a species under one term, then at the close of the description stating that in all probability it does not belong to the species referred to but is probably a new species, then proposing the name at the end of the whole description.*

One of the specimens obtained was fortunately covered with young specimens of whose relation there can be no doubt as *Derbya multistriata* is the only Derbya in this horizon at Torrence where these specimens were found. The smallest specimen measured a trifle over 1 mm. wide. In a specimen 5 mm. wide the mesial septum is well developed.

The high cardinal area is well illustrated by the measurements of a small specimen. The pedicle valve length was 1½mm. and width 3 mm. The cardinal area was nearly square and measured 3 mm. x 2 mm., or larger than the pedicle valve. At no time in its development was it seen to have a form identical with the typical adult *D. crassa*.

††Kansas River Section of the Permian and Permo-Carboniferous Rocks of Kansas. Bull. Geol. Soc. Amer., VI, p. 40, 1894.

||Description des Animaux Fossiles de Koninck, pp. 222-224 and Pl. XIII, fig. 4a, b, c et fig. 7, a, b, c, et Pl. XIII bis. fig. 7, a, b.

§§Lethaea Geognostica Bronn, pp. 368-363 and Pl. II¹, fig. 11, a, b, c.

*Pal. N. Y., Vol. VIII, Pt. I, page 348 Pl. 11b, fig. 2-3.

## LIST OF SPECIES.

| | | |
|---|---|---|
| 1. | Fusulina sp | 800 |
| 2. | Lophophyllum profundum Edwards and Haime | 1 |
| 3. | Crinoidea sp. (plates and segments) | .. |
| 4. | Ceriocrinus hemisphericus (Shum.) | 1 |
| 5. | Pholidocidaris sp. (spine) | .. |
| 6. | Archeocidaris sp. (spines and plates) | .. |
| 7. | Rhombopora lepidendroides Meek | 30 |
| 8. | Stenopora carbonaria (Worthen) | 30 |
| 9. | Fenestella sp. | .. |
| 10. | Fistulipora sp | .. |
| 11. | Streblotrypa prisca Gabb and Horn | .. |
| 12. | Septopora sp | .. |
| 13. | Thamniscus sp | 30 |
| 14. | Bryozoa sp. | .. |
| 15. | Bryozoa sp. | .. |
| 16. | Bryozoa sp. | .. |
| 17. | Orbiculoidea convexa (Shum.) | 2 |
| 18. | Crania modesta White and St. John | 67 |
| 19. | Strophalosia sp. | 27 |
| 20. | Dielasma bovidens (Morton) | 8 |
| 21. | Seminula argentia (Shepard) | 44 |
| 22. | Meekella striatacostata (McChesney) | 31 |
| 23. | Productus semireticulatus (Martin) | 39 |
| 24. | Productus nebrascensis Owen | 84 |
| 25. | Chonetes granulifera Owen | 293 |
| 26. | Derbya crassa (Meek) | 79 |
| 27. | Derbya robusta(?) (Hall) | 1 |
| 28. | Derbya multistriata (Meek and Hayden) | 9 |
| 29. | Ambocoelia planoconvexa (Shum.) | 10 |
| 30. | Pugnax utah (Marcou) | 4 |
| 31. | Psuedomonotis hawni Meek | 11 |
| 32. | Myalina kansasensis Shum. | 21 |
| 33. | Myalina swallowi? (McChesney) | 1 |
| 34. | Myalina sp. | 1 |
| 35. | Aviculopinna nebrascensis Beede | 2 |
| 36. | Schizodus wheeleri Swallow | 21 |
| 37. | Schizodus sp. | 2 |

| | | |
|---|---|---|
| 38. | Edmondia nebrascensis Meek | 1 |
| 39. | Edmondia reflexa Meek | 3 |
| 40. | Edmondia (?) 2 sp | 2 |
| 41. | Allorisma subcuneatum Meek | 2 |
| 42. | Sedgewickia granosum (Shum.) | 3 |
| 43. | Allorisma sp | 1 |
| 44. | Aviculopecten maccoyi M. and H | 1 |
| 45. | Chaenomya leavenworthensis M. and H | 1 |
| 46. | Pteria ohioensis (Herrick) | 20 |
| 47. | Pteria sulcata Geinitz | 128 |
| 48. | Entolium (?) sp | 1 |
| 49. | Nucula sp | 3 |
| 50. | Nucula ventricosa McChesney | 1 |
| 51. | Yoldia sp | 5 |
| 52. | Macrodon sp | 1 |
| 53. | Aviculopecten occidentalis (Shum.) | 40 |
| 54. | Nuculana bellistriata attenuata Meek | 42 |
| 55. | Pleurophorus sp | 1 |
| 56. | Pelecypod young species | 200 |
| 57. | Bulimorpha chrysalis (Meek and Worthen) | 25 |
| 58. | Euomphalus catelloides (Conrad) | 25 |
| 59. | Bellerphon carbonaria Cox | 3 |
| 60. | Pleurotomaria sp | 11 |
| 61. | Bellerphon sp | 39 |
| 62. | Capulus sp | 1 |
| 63. | Euconispira sp | 1 |
| 64. | Gastropod sp. (Aclis (?)) | 300 |
| 65. | Gastropod sp | 200 |
| 66. | Orthoceritite sp | 2 |
| 67. | Bairdia beedei Ulrich and Bassler | 100 |
| 68. | Bairdia beedei abrupta U. and B | 25 |
| 69. | Kirkbya pinguis U. and B | 1 |
| 70. | Paraparchites humerosus U. and B | 1 |
| 71. | Beyrichella bolliformis tumida U. and B | 1 |
| 72. | Ostracod sp | 2 |
| 73. | Griffithides scitula (Meek and Worthen) | 9 |
| 74. | Cladodus mortifer Newberry and Worthen | 2 |

## EXPLANATION OF PLATES.

### Plate I.

*Derbya multistriata* (Meek).

1. a. b. c. Reproduced from de Koninck's, pl. XIII, f. 7, a, b, c.

2. Figure 7a. pl. XIII bis. of de Koninck. These specimens are called "Orthis umbraculum" by him, but are very different from those figured by Bronn, from the Devonian of Eiffel, after examining Schlotheim's types.

3a. Specimen below average size, but possessing an unusually high hinge area which is symmetrical, posterior view.

3b. Lateral profile of same specimen.

All figures natural size.

PLATE I.

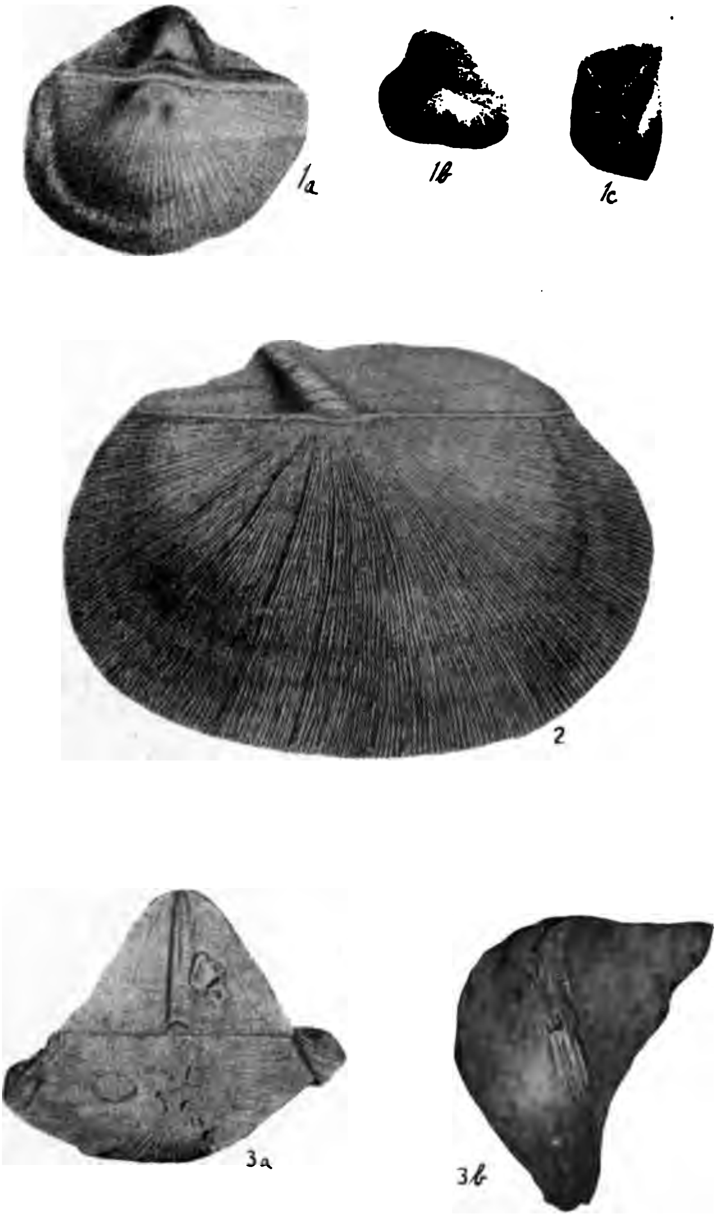


PLATE II.

*Derbya multistriata* (Meek).

1. Brachial valve of specimen with high area extending nearly backward, due partly to compression.

2. Same view of another specimen with low beak and normal brachial valve.

3. Pedicle valve of another specimen showing surface marks and thirteen young specimens adhering to it. They are of the same species.

3a. Profile of number 3. Pedicle valve uppermost.

4. A profile of another and smaller specimen with a high and distorted hinge area. Pedicle valve uppermost.

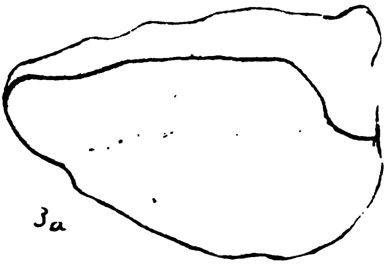
All figures natural size.

PLATE II.

1

2

3



3a

4

PLATE III.

*Derbya multistriata* (Meek).

1. Brachial valve of a specimen with an extremely elongated beak. Shell adhering to it.

2. Brachial valve of another specimen showing its regular form and the surface marks.

3. Another specimen, profile view, with beak extending backward and twisted to the right.

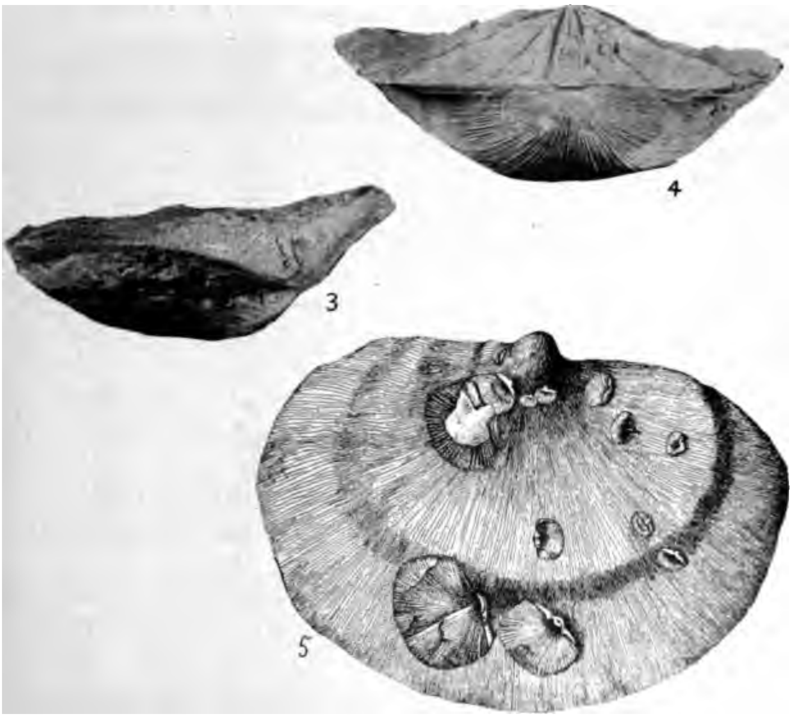
4. Posterior view of another specimen with a hinge a shade lower than normal.

5. A pen drawing of No. 3 of previous plate. Note the mesial septum in the little specimen, the central one of the three to the right of the beak, which is only five millimeters in diameter.

All figures natural size.

With the exception of figures 1 and 2 of plate I, all specimens are from the top of the Neosho member of the Garrison formation, in the railroad cut on the west side of Grouse creek, near the old station of Torrence, Kansas, a few miles west of Cambridge.

PLATE III.

# Observations on the Formation and Enlargement of the Tubes of the Marine Annelid, (*Chaetopterus Variopedatus*).

Howard E. Enders.

*Chaetopterus variopedatus* is a widely distributed tubiculous annelid of the family Chaetopterida. The individuals of each country and of widely distributed areas in Europe were classified as distinct species till Joyeux-Laffuie showed conclusively, in 1890, that they are really a single species. He also suggested that a close study of the species in foreign seas would probably result in referring them to a single species. A careful comparison of the specimens found at Beaufort, North Carolina, with Joyeux-Laffuie's detailed description of *Chaetopterus variopedatus*, leads me to regard the American representative, which Verrill and E. B. Wilson named *Chaetopterus pergamentaceus*, as identical with the single European form.

This peculiar species of sedentary annelid is found in several localities in the harbor of Beaufort, North Carolina, where the conditions for its existence are afforded by the extensive sand-flats, either covered with a thick growth of diatoms or continually exposed to currents of water heavily charged with these plants. It is here found living within its broadly U-shaped parchment tubes in nearly every portion of the harbor wherever the sand-flats are formed in the quieter waters.

The presence of Chaetopterus may be recognized by the extremities of the U-shaped tubes that usually protrude several centimeters above the level of the shoal (Fig. 3). The extremities of some tubes are concealed by ascidians, colonies of bryozoans or of hydroids, attached to them so that it may be difficult to detect the circular whitish openings within the cluster of attached animals.

The animal remains within its tube during its whole life but, as the animal grows in size, it increases both the length and the diameter of its tube. The horizontal portion of the U is of greater diameter than the conical vertical arms that protrude a few centimeters above the sub-

stratum. The simple U-form is often modified in tubes that occur in shoals of sand and shells. The arms may here be so constructed that they turn abruptly aside from large shells that are in their way. Tubes with three arms are frequently found (Fig. 4). These are tubes that have been enlarged by the extension of the horizontal portion and the formation of a new (vertical) arm. A septum at the base of the intermediate arm separates its cavity from that of the horizontal portion. I have found intermediate arms with little or no sand, some completely filled, while many have begun to macerate. Every large tube bears the shreds of one or more of these macerated intermediate arms, or the crescentic scars that mark their former union with the newly formed extension. The annulations near the orifices and the longitudinal strips of thinner, sand-covered, parchment alternating with the thicker portion of the tubes represent successive steps in the formation and enlargement of the tubes.

There is great diversity in the size of the tubes. A very young worm formed a characteristic U-shaped tube three millimeters in diameter at its wider portion, and one and three-fourths millimeters at its orifices. The distance between the orifices measured fourteen and one-half millimeters, and the length of the arms (measured from the lower side of the horizontal portion to its base) was sixteen millimeters. I have collected tubes which ranged in length from six to fifty centimeters and with arms six to twenty-two centimeters long.

The formation of the first tube and the subsequent enlargements was observed on larvae of *Chaetopterus variopedatus* which I was fortunate enough to collect in the tow-net. These larvae, which were transforming from the free-swimming mesatrochae into the creeping individuals, were kept in aquaria of sea water well stocked with diatoms. When the larvae move among the diatoms they leave a trail of mucus that cements the sand and diatoms together. Later they make short, horizontal, mucus-coated tunnels into the mass of diatoms and sand. One of these tunnels may be extended to several times the length of the body and from this simple tunnel of agglutinated sand and diatoms the larvae may build the tube within which it subsequently remains confined.

The first tube in which the larvae lives and feeds for several days is nearly a millimeter in diameter and from eighteen to twenty-two millimeters long. It is either a straight tube or a shallow U whose curved portion is downward.

After an interval of a day or two in the mucus-coated tunnel the young worm, for it is now an adult in miniature, has outgrown it and a new tube is constructed. This is done by splitting the tube at a point where the upright arm meets the horizontal portion, in a U-shaped tube, or near one end, in a straight tube, and then excavating a tunnel obliquely downwards and after nearly doubling the length of basal portion upwards to the surface. This is its first lateral enlargement. The sand which the worm excavates in constructing this extension is expelled from the opposite end of its first tube. The walls of the tunnel are coated with mucus as the tunnel advances, so that the U-shaped tube is completed when the excavation reaches the surface. The tube becomes strengthened from time to time by additional layers of mucus that hardens to form a parchment-like material that gives the older tubes a laminated structure. They are enlarged in the same vertical plane unless prevented from doing so by some obstruction, as a shell, when they turn obliquely along the surface of the obstruction or abandon the new enlargement and construct an enlargement from the opposite end of the tube. Two or three days later the process is repeated, possibly by the extension of the opposite end of the tube. The horizontal portion of each new enlargement is larger in diameter and is buried deeper in the sand than the tube from which it is a branch (Fig. 4). Enlargements are frequently of such length as to double the size of the U-tube, and are completed to the surface of the sand in from twenty-four to forty-eight hours. They are made indifferently at one end or other of the smaller tube. The fate of the intermediate tubes has been discussed in another part of the present paper.

The burrowing is done by the anterior region of the worm. Its setigerous segments dislodge the sand and pass it to the middle and posterior regions of the body, and they convey it backwards into the tube by the combined contraction and expansion of the body, and the rythmic movements of the palettes and lobes of the segments. The worm ceases burrowing at intervals of a few minutes and expels the accumulated sand at one end of the tube around which it falls and forms a mound; the other end, or intermediate tube, is the incurrent tube so long as the burrowing is in progress, but when the new burrow is complete a septum of parchment is formed across the base of the intermediate tube and it ceases to be of any use to the worm.

The worms which form their tubes in aquaria with a thin layer of sand

and diatoms on the bottom conform to the U-habit, though in a horizontal plane, with one side of the tube cemented to the floor of the vessel.

The linear extensions of the tubes are formed at such intervals as the rapid growth of the worm requires. The length of the tubes, and the dates on which the enlargements were completed by two worms which I reared from larvae taken in the tow-net are as follows:*

| SPECIMEN No. 2. | | SPECIMEN No. 4. | |
|---|---|---|---|
| Distance between arms. | Date. | Distance between arms. | Date. |
| 20 mm. | August 7, 1905. | 20 mm. | August 7, 1905. |
| 38 mm. | August 10, 1905. | 32 mm. | August 9, 1905. |
| 60 mm. | August 15, 1905. | 61 mm. | August 16, 1905. |

Early in September of 1905 I collected three worms whose tubes averaged fifty-one millimeters between the orifices and five whose recently discarded intermediate arms were sixty millimeters from the ends with which they formed the smaller U-shaped tubes. The horizontal extensions increased their length to fifteen centimeters in the smallest and twenty-two and one-half in the longest specimen. Many thick-walled tubes are found with scars of intermediate arms which indicate that they were increased from about this size to about forty centimeters. The longest tubes show that they were increased, by a linear extension of ten centimeters, to fifty centimeters.

The tubes also undergo an enlargement in diameter as the animal grows in thickness. This splitting and enlargement of one of its arms I observed in specimen No. 4 during one night in September of 1905. The worm pushed the rim of the buccal funnel nearly to the margin of the orifice, and slowly moved the ends of the tentacles over the rim of the tube. (In order to enter this narrow portion of the tube from below the edges of the buccal funnel and anterior region of the body was curved dorsalwards and considerably contracted till they become conical in form.) The animal remained in this position in the tube about five seconds then slowly withdrew into the deeper portion. This was repeated in thirty seconds but this time it withdrew only to the level of the sand. Here the worm suddenly

*Both worms enlarged their tubes to 76 and 71 millimeters, respectively, between September 12th, when they were brought to the Biological Laboratory of the Johns Hopkins University, and my return, October 4, 1905. The worm in No. 4 had extended its tube to the glass wall of the aquarium on May 8-9, 1906. The U-shaped tube now measured 85 millimeters between the orifices.

expanded the first pair of setigerous segments and split the tube longitudinally at its outer side, then withdrew quickly into the deeper portion of the tube. Fifteen or twenty seconds later the worm reappeared at the level of the sand, extended the rent a little higher and withdrew. This action was repeated five times in extending the rent, seven millimeters, to the end of the tube. The rent was produced by means of the expansion of the muscular setigerous region and not by the sharp lance-shaped setae as one might suppose. The rent occurred in a position opposite the ventral surface of the body. When the tube was split to its extremity the worm thrust one side of the anterior region through the cleft and removed the sand about it by means of its setigerous notopodia. They pressed a portion of the sand aside but some was removed backwards into the tube and later discharged at the other end.

When the tube was split to its end the worm spread the basal portion of the rent by a slight expansion of the ventral side of its lower lip and the foremost portion of the anterior region. The worm remained in this position for fifteen or twenty seconds then withdrew into its tube for a half minute, after which it took a position a little nearer to the orifice of the tube. The performance was repeated till the edges were reunited by a wedge-shaped insertion of parchment that widened to three millimeters just below the level of the sand. I could not determine which region of the body was most active in the secretion of the mucus, which becomes parchment-like, but I observed that it was shaped by the lower lip of the buccal funnel, and that the parchment film had advanced a little higher each time the animal applied its ventral lip to the cleft. The splitting of the tube and the closure of the rent were completed in thirty-five minutes.

The splittings occur indifferently on any portion of the circumference of the tube, but they are found chiefly on the upper side of the horizontal portion. When they are extensive it is indicated by the abundance of sand discharged at long intervals from one arm of the tube. I have found some large tubes that had strips of thin parchment two centimeters wide and as long as the horizontal portion of the tube.

The new portion of the wall is thin and membranous at first and, while it becomes thicker with age, can be observed, long after its formation, as a strip somewhat thinner than the remaining portions of the wall. Its inner surface is smooth, like the inner wall of the other portion, and its outer surface is similarly covered with sand. The wide, horizontal portion of nearly every tube bears one or more of these strips inserted between the

edges of a thicker laminated wall. This was true even in the smallest specimens, No. 2 and No. 4, which I mentioned on page 131. The diameter of their tubes was twice enlarged while they were thirty-eight and thirty-two millimeters long, respectively, and before they constructed the next linear enlargement.

The outer surface of the tubes is everywhere coated with sand, excepting about the terminal portions that protrude above the sand flats in which they are imbedded. These terminal portions have one or more annulations that give them the appearance of being formed of rings that diminish regularly in size upwards, so that the bases of the smaller rings are overlapped by the top of the rings next below. Each ring represents the successive height of the orifice, though not its diameter, for they are split from time to time as I have just mentioned. They are moulded, like the other portions of the tube, by the ventral lip of the buccal funnel, and the length of each ring represents the height to which the lip was extended when the ring was formed. The rings are, at first, very thin and transparent but they become laminated by successive additions of mucus to their inner walls. The laminae of which they are the free ends may be separated with ease from those next below.

## SUMMARY.

The principal points that I have attempted to bring out in this paper are:

1. The tubes are formed by the worm from mucus secreted by certain cells of the body. Before the mucus hardens to a parchment-like material it is molded by the ventral lip of the buccal funnel.

2. The tubes are first formed as tunnels in the diatoms, but later they have the form of a U.

3. The tubes are enlarged either in length or diameter or by a combination of both these methods.

PLATE I.

Fig. 1. View of dorsal side of female Chaetopterus Variopedatus. (½ Nat.)

Fig. 2. Dorsal view of male Chaetopterus removed from its tube. (½ Nat.)

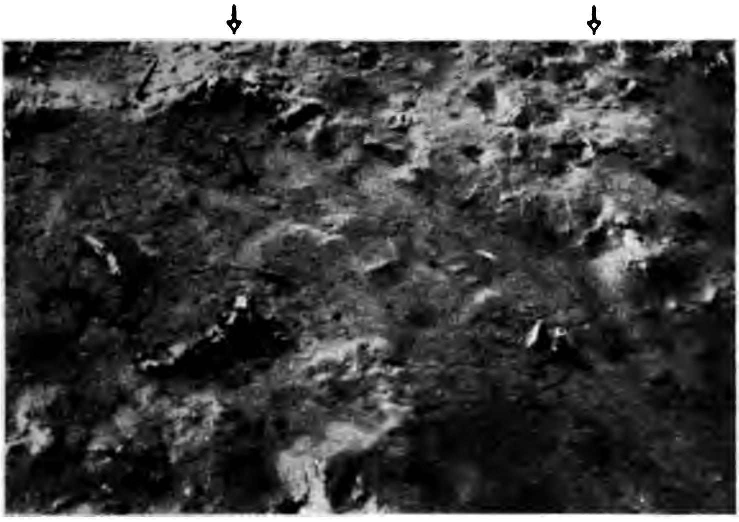


PLATE II.

Fig. 3. View of two orifices of the tube of Chaetopterus at low tide.

Fig. 4. Photograph of tube to show lateral enlargement and position of the discarded intermediate arm. (½ Nat.)

# Notes on the Artificial Fertilization of the Eggs of the Common Clam, (*Venus Mercenaria*).

H. E. Enders and H. D. Aller.

In view of the economic importance of the common clam we endeavored to artificially fertilize its eggs during the past summer* at the United States Fisheries Laboratory, at Beaufort, North Carolina. Many clams were full of eggs or contained active spermatozoa when we first examined them in July. This condition prevailed till the 12th of September, but early in November of this year the spermatozoa were not active.

Several times during July and August we fertilized the eggs by the addition of active spermatozoa from several males and observed the maturation of the egg, the segmentation, and the early trochophore stage. In one instance (August 1, 1906) the development continued to the young veliger stage.

The female sexual element is a pear-shaped cell in which a large germinal vesicle is found. Many of the cells become spherical fifteen or twenty minutes after the addition of active spermatozoa. The eggs then show no further evidence of being fertilized till two hours after the addition of sperm, when the first polar body is cast off and this followed by the second at an interval of twenty or thirty minutes. Thirty minutes later the egg passes into the two-celled stage by a holoblastic and unequal division. The next division occurs in a plane at right angles to the first and this is followed by division in a plane at right angles to the other two.

The cells divide synchyonously up to the thirty-two-celled stage but we were unable to determine whether this continues beyond this stage.

The percentage of eggs that could be fertilized was small during July; it increased during August and September, but during November the spermatozoa were not active and the eggs could not be fertilized.

While we have not reached a definite conclusion regarding the breeding habits of the common clam we feel that these data are themselves significant.

*Summer of 1905.

# Determination of all Surfaces for Which, When Lines of Curvature are Parameter Lines (u=const., v=const.), the Six Fundamental Quantities, E, F, G, L, M, N, are Functions of One Variable Only.

Wm. H. Bates.

The following simplifications come out of the data:

(1) $F = 0 = M$ (Since lines of curvature are parameter lines).

(2) The v — derivatives of E, G, L, N vanish. (Since the latter are functions of u only.)

(3) We may substitute for u a function defined by the equation,

$$E du^2 = du'^2,$$

which makes E, G, L, and N functions of u′ only. Also the system of parameter curves is (as a whole) not changed, for when $u = \text{const}$, $u' = \text{const}$ also. Now if we drop the prime from u′, the substitution has exactly the effect of making $E = 1$.

Let $(X_1, Y_1, Z_1)$ and $(X_2, Y_2, Z_2)$ be direction cosines of tangents to the v-curve and u-curve at any point of the surface. These tangents, together with the normal to the surface (direction cosines of which are X, Y, and Z) at the point form a rectangular system of axes.

$$(1)\quad X_1 = \frac{\partial x}{\partial u};\ Y_1 = \frac{\partial y}{\partial u};\ Z_1 = \frac{\partial z}{\partial u}\ (\text{since } E = 1).$$

$$(2)\quad X_2 = \frac{1}{\sqrt{G}}\frac{\partial x}{\partial v};\ Y_2 = \frac{1}{\sqrt{G}}\frac{\partial y}{\partial v};\ Z_2 = \frac{1}{\sqrt{G}}\frac{\partial z}{\partial v}$$

Then the differential equations for the general surface (see Bianchi, 1902 Edition, p. 123) become after introducing the above simplifications,

$$(3)\quad \frac{\partial X_1}{\partial u} = LX$$

$$(4)\quad \frac{\partial X_1}{\partial v} = \frac{d\sqrt{G}}{du} X_2$$

$$(5)\quad \frac{\partial X_2}{\partial u} = o$$

$$(6)\quad \frac{\delta X_2}{\delta v} = \frac{N}{\sqrt{G}} X - \frac{d\sqrt{G}}{du} X_1$$

$$(7)\quad \frac{\delta X}{\delta u} = -LX_1$$

$$(8)\quad \frac{\delta X}{\delta v} = -\frac{N}{\sqrt{G}} X_2$$

and similar equations for Y and Z.

NOTE. These, together with the simplified Gauss and Codazzi equations, should give by integration the required surfaces. In the attempt to perform the integration, the following geometric solution was reached. I hope to complete the solution by integration later.

*The v-curves make principal sections.*

The equation of principal normal to the surface is

$$\frac{\xi - x}{\frac{d^2x}{ds^2}} = \frac{\eta - y}{\frac{d^2y}{ds^2}} = \frac{\zeta - z}{\frac{d^2z}{ds^2}}$$

$$\frac{dx}{ds} = \frac{dx}{ds_v} \text{ along v-curve}$$

$$= \frac{dx}{du}, \text{ since } ds_v = \sqrt{E}\, du = du$$

$$= \frac{\delta x}{\delta u} + \frac{\delta x}{\delta v}\frac{dv}{du}$$

$$= \frac{\delta x}{\delta u}, \text{ since } v = \text{const.}$$

$$= X_1$$

$$\frac{d^2x}{ds^2} = \frac{\delta X_1}{\delta u} = LX.$$

Similarly for y and z, giving

$$\frac{\xi - x}{x} = \frac{\eta - y}{y} = \frac{\zeta - z}{z}$$

which is the normal to the surface at (x, y, z).

*The v-curves are also plane curves.*

Torsion $\frac{1}{T} = \sqrt{\left(\frac{d\lambda}{ds}\right)^2 + \left(\frac{d\mu}{ds}\right)^2 + \left(\frac{d\nu}{ds}\right)^2}$ where $\lambda$, $\mu$, $\nu$ are direction cosines of bi-normal to curve (here $X_2$, $Y_2$, $Z_2$)

$$\frac{dX_2}{ds_v} = \frac{dX_2}{du} = \frac{\partial X_2}{\partial u} = o \text{ and similarly } \frac{dY_2}{ds} = o = \frac{dZ_2}{ds} \;\therefore\; \frac{1}{T} = o.$$

*The u-curves have constant radius of curvature.*

The equation of radius of curvature is,

$$\frac{1}{\rho^2} = \left(\frac{d^2x}{ds^2}\right)^2 + \left(\frac{d^2y}{ds^2}\right)^2 + \left(\frac{d^2z}{ds^2}\right)^2$$

$$\frac{dx}{ds} = \frac{dx}{ds_u} = X_2$$

$$\frac{d^2x}{ds^2} = \frac{d}{ds_u} X_2$$

$$= \frac{\partial X_2}{\partial v}\frac{dv}{ds_u}$$

$$= \frac{1}{\sqrt{G}}\frac{\partial X_2}{\partial v}, \text{ since } ds_u = \sqrt{G}\, dv$$

So,

$$\frac{d^2x}{ds^2} = \frac{1}{\sqrt{G}}\left(\frac{N}{\sqrt{G}} X - \frac{d\sqrt{G}}{du} X_1\right)$$

$$\frac{d^2y}{ds^2} = \frac{1}{\sqrt{G}}\left(\frac{N}{\sqrt{G}} Y - \frac{d\sqrt{G}}{du} Y_1\right)$$

$$\frac{d^2z}{ds^2} = \frac{1}{\sqrt{G}}\left(\frac{N}{\sqrt{G}} Z - \frac{d\sqrt{G}}{du} Z_1\right)$$

$$\frac{1}{\rho^2} = \frac{1}{G}\left[\frac{N^2}{G}\Sigma X^2 - 2\frac{N}{\sqrt{G}}\Sigma X_1 X + \left(\frac{d\sqrt{G}}{du}\right)^2 \Sigma X_1^2\right]$$

$$\Sigma X^2 = 1 = \Sigma X_1^2 + \Sigma X_1 X = o$$

$$\frac{1}{\rho^2} = \frac{1}{G}\left[\frac{N^2}{G} + \left(\frac{d\sqrt{G}}{du}\right)^2\right]$$

$= $ function of u only.

$\therefore$ const for u-curves.

*The u-curves are also plane curves, and therefore circles.*

We may write equation of torsion in the form,

$$\frac{1}{T} = -\rho^2 \begin{vmatrix} x' & y' & z' \\ x'' & y'' & z'' \\ x''' & y''' & z''' \end{vmatrix}$$

(where primes denote derivatives with respect to s).

From last paragraph we have for u-curves,

$$x'' = \frac{d^2x}{ds^2} = \frac{1}{\sqrt{G}} \frac{\partial X_2}{\partial v}$$

$$x''' = \frac{d}{ds_{u}}\left(\frac{1}{\sqrt{G}} \frac{\partial X_2}{\partial v}\right)$$

$$= \frac{\partial}{\partial v}\left(\frac{1}{\sqrt{G}} \frac{\partial X_2}{\partial v}\right)\frac{dv}{ds_{u}}$$

$$= \frac{1}{G} \frac{\partial^2 X_2}{\partial v^2}$$

$$= -\frac{1}{G}\left[\frac{N^2}{G} + \left(\frac{d\sqrt{G}}{du}\right)^2\right] X_2 \text{ from (6), (4) and (8)}$$

$$x''' = \phi(u)\, X_2$$

$$\text{So } y''' = \phi(u)\, Y_2$$

$$z''' = \varphi(u)\, Z_2$$

$$\frac{1}{T} = -\rho^2\phi(u)\frac{1}{\sqrt{G}} \begin{vmatrix} X_2 & Y_2 & Z_2 \\ \frac{\partial X_2}{\partial v} & \frac{\partial Y_2}{\partial v} & \frac{\partial Z_2}{\partial v} \\ X_2 & Y_2 & Z_2 \end{vmatrix} = 0$$

Since the u-curves are plane and have constant radi of curvature they are circles.

Finally, the plane of each v-curve is normal to every u-circle, and therefore passes through its center. The intersection of any two v-planes determines the line of centers of the u-circles. Thus all the required surfaces are surfaces of revolution. Taking the line of centers of u-circles as z-axis and the plane of any u-circle as xy-plane, the equation of our surfaces are

$$\begin{cases} x = u \cdot \cos v \\ y = u \cdot \sin v \\ z = f(v) \end{cases}$$

# Lines on the Pseudosphere and the Syntractrix of Revolution.

E. L. Hancock.

## INTRODUCTION.

Consider two surfaces of revolution S and $S_1$ generated by the revolution of the curves C and $C_1$ about the Z axis. $C_1$ is formed by taking on the tangents to C distances equal to the constant-k′ times the length of the tangents. The length in each case is measured from the z-intercept toward the point of tangency. Let C = O be given by $z = f(u)$, then $C_1 = O$ will be given by,

$$z_1 = (L-1)u_1 f'(Lu_1) + f(Lu_1)$$

where $L = 1 \, k'$ and the equations of transformation from S to $S_1$ are,

$$\begin{aligned} u &= Lu_1 \\ v &= v_1 \end{aligned} \qquad \ldots\ldots(1)$$

When the length of the tangent to the curve C is constant, as in the tractrix, the curve $C_1$ is the syntractrix (see Note), and the surfaces S and $S_1$ are therefore the pseudosphere and the syntractrix of revolution.

What follows is the study of lines on these surfaces. The geodesic lines on the pseudosphere have been studied by means of lines in the plane. This surface being one of constant negative curvature (—1) may, according to Beltrami (see Note 2), be represented geodesically by a system of straight lines in the plane.

Much of the work outlined here for geodesics on the pseudosphere may be found in Darboux, Theorie des Surfaces, Vol. III, and is given here only in the way of review and for completeness.

The claim made for the originality in this part of the work is in (1) the classification of the geodesic lines and the study of certain systems of geodesic lines and their corresponding lines in the plane; (2) *the transformations of the system of circles* into straight lines by making use of the sphere,

Note 1.—The syntractrix is defined as the curve generated by taking a constant distance on the tangents to the tractrix. Peacock, p. 175.

Note 2.—Beltrami, Annali di Matematica. Vol. 7, p. 185
Bianchi, Lukat, Differential—Geometrie, p. 436.

as indicated; (3) the study of the asymptotic lines and the loxodromic lines on the pseudosphere and their representations in the plane.

In the second part of the work the lines on the syntractrix of revolution are studied. This work so far as I know has never been done before In it I have worked out the equations of the geodesic, asymptotic and loxodromic lines. These have been studied in particular by classifying the surfaces $S_1$ according as $d \gtreqless 2C$, where C is the length of the tangent to the tractrix and d the constant distance taken on that tangent. When $d \geqq 2C$ it happens that the geodesic lines on $S_1$ are all real and that the geodesic lines for $d < 2C$ are real or imaginary according as $r^2 \gtrless \left| k_1/k \right|$.

The loxodromic lines are represented in the plane by the same system of straight lines as the loxodromic lines of the pseudosphere. The drawings are given for the sake of clearness.

## CHAPTER I.

### Geodesic Lines on the Pseudosphere.

Taking the equation of the tractrix in the form,

$x = C \cosh.^{-1} c\, y - (C^2 - y^2)^{1/2}$ we get for the given surface,

$$x = u \cos v \qquad \ldots\ldots(2)$$
$$y = u \sin v$$
$$z = C \cosh.^{-1} c/u - (C^2 - u^2)^{1/2}$$

and the fundamental quantities of the Gaussian (see Note 1) notation are, $E = C^2/u^2$, $F = 0$, $G = u^2$, $D = (C^2)/(u(C^2 - u^2)^{1/2})$, $D' = 0$, $D'' = -u(C^2 - u^2)^{1/2}$, $K = -1$.

Using the method of calculus of variations as developed by Weierstruss (see Note 2) to obtain the equations of the geodesic lines, we have to minimize the integral,

$$I = \int_{t_0}^{t} (E du^2 + 2F du dv + G dv^2)^{1/2} dt$$
$$= \int_{t_0}^{t} ((C^2 u'^2)/(u^2) + u^2 v'^2)^{1/2} dt = \int_{t_0}^{t} \bar{F} dt$$

Legendre's condition for a minimum is $\bar{F}v - (d/dv)\bar{F}v' = 0$ where $(\bar{F}v) = (\delta \bar{F})/(\delta v)$ and $\bar{F}v' = (\delta F)/(\delta v')$.

Here $\bar{F}v = 0$, so that we get as the equations of the geodesics

$$\bar{F}v' = (u^2 v')/((C^2 u^2/u^2) + u^2 v'^2)^{1/2} = \alpha \qquad \ldots\ldots(3)$$

Where $\alpha$ is the constant of integration.

Note 1.—Bianchi, Differential-Geometrie, pp. 61 and 87.

Note 2.—Kneser, Variationsrechnung.
Osgood, Annals of Mathematics, Vol. 2, p. 105.

In considering these curves two cases may arise, (1) when $\alpha = 0$, (2) $\alpha \pm 0$. Case (1) when $\alpha = 0$, either $u = 0$ or $v' = 0$. But $u \pm 0$ hence $v' = 0$ and so $v =$ constant. That is the meridians are geodesics.

Case (2) when $\alpha \pm 0$, (3) becomes

$$v = (C/\alpha u)(u^2 - \alpha^2 C^2)^{1/2} + \beta \qquad \ldots\ldots(4)$$

This may, however, be put in a more convenient form, since in the present case the geodesic lines $v =$ constant all meet in a point and the curves $u =$ constant form a system of geodesic circles — the orthogonal trajectories of the meridians. Under such conditions E may be equated to unity (see Note 1). The new $u_2$ is then given by the relation $u_2 = \int (E)^{1/2} du$. Hence $u = e^{u_2/c}$. Replacing in (4) $u$ by its value just found the equation of the geodesic lines becomes

$$v = (C/\alpha)(1 - \alpha^2 e^{-2u/c})^{1/2} + \beta \qquad \text{(see Note 2)} \ldots\ldots(5)$$

This equation may be used to determine the allowable values of $\alpha$ and $\beta$. The constant $\beta$ being additive has no effect except to turn the surface about the z axis. Thus a geodesic line given by one value of $\beta$ may be made to coincide with one given by another value of $\beta$ by revolution about the z axis, $\alpha$ remaining constant. $\beta$ may vary from $-\infty$ to $+\infty$.

From (5) it is seen that the lines are real or imaginary according as

$$\alpha^2 e^{-2u/c} \gtreqless 1,$$

(1) Let $\alpha^2 e^{-2u/c} > 1$, then $|\alpha| > e^{u/c}$.

But for the pseudosphere $u_2 < C \log C$ so that the geodesics will be imaginary when $|\alpha| > C$. (2 & 3). Let $\alpha^2 e^{-2u/c} \leqq 1$, then $|\alpha| \leqq e^{u/c}$.

Hence $|\alpha| \leqq C$ gives real geodesics.

Equations (5) may be transformed into

$\alpha^2(v^2 + C^2 e^{-2u/c}) - 2\beta\alpha^2 v + (\beta^2 \alpha^2 - C^2) = 0$ which when

$$v^2 + C^2 e^{-2u/c} = y$$

$$v = x \qquad \ldots\ldots(6)$$

may be represented in the plane by the straight lines,

$$y = 2\beta x - (\beta^2 - C^2/\alpha^2) \qquad \ldots\ldots(7)$$

(6) may be broken up into two transformations

(a)
$$\left.\begin{array}{l} v = x \\ Ce^{-u/c} = y \end{array}\right\} \ldots\ldots(8)$$

Note 1.—Knoblauch, Theorie der Krummen Flächen, p. 133.

Note 2.—Bianchi, p. 419.

which transforms S conformally on the plane so that the geodesics lines go over into the circles,

$$(x-\beta)^2+y^2=C^2/\alpha^2 \qquad \text{(See Note 1)}$$

and (b)

$$\left.\begin{aligned} y &= (y-x^2)^{1/2} \\ x &= x \end{aligned}\right\} \quad \ldots\ldots(9)$$

which changes the circles into the straight lines,

$$y=2\beta x-\beta^2+C^2/\alpha^2 \qquad \ldots\ldots(10)$$

By (9) the x axis goes into the parabola $x^2=y$ and all the lines $y=$ constant go into the parabolas $x^2=y+$ constant. The whole upper part of the plane is represented inside the parabola $x^2=y$. The points on the lines $x=$ constant are moved along the lines. The origin is the fixed point of transformation.

Circles concentric at the origin correspond to lines $y=$ constant while every system of concentric circles on the x axis goes over into a system of parallel lines. A system of circles given by (8) passing through a point corresponds to a system of lines through a point. A system of circles with the y axis as radical axis

$$x^2+y^2-2\beta x+k^2=0$$

and their orthogonal trajectories,

$$x^2+y^2-2hy=\pm d^2 \qquad \text{(See Note 2)}$$

corresponds to a sheaf of lines and a sheaf of conics.

The geodesics $v=$ constant correspond to the lines $x=$ constant i. e. to the diameters of the parabola $x^2=y$. The entire real part of the surface S is represented in the xy—plane by the strip $y=0$ $y=C/e$ and in the xy—plane by the strip included by the curves $x^2=y-C^2$ and $x^2=y-C^2/e^2$. The circles of (8) tangent to the line $y=C/e$ go over into a system of straight lines enveloping the parabola $x^2=y-C^2/e^2$.

Since the representation given by (8) is conformal it is interesting to note that the lines $y=$ constant may be considered as the envelop of a system of circles of constant radii and centers on the x axis given by the equation,

$$(x-\beta)^2+y^2=C^2/k^2$$

corresponding on the surface to the geodesics,

$$v^2+C^2e^{-2u}/c-2\beta v+(\beta^2-C^2/k^2)=0 \qquad 0<k\leq e$$

Note 1.—Bianchi, p. 419.

Note 2.—Salmon's Conic Sections, p. 100.

These may be regarded as a system of geodesics having as an envelop the

geodesic circles $u = k_1$ $0 < k_1 < C$. A system of concentric circles with the centers at any point $(e, 0)$ on ox gives the geodesics

$$v^2 + C^2 e^{-2u/c} - 2ev + e^2 - C^2/\alpha^2 = 0$$

If $\alpha . \beta = C$ we get a system of circles through the origin

$$x^2 + y^2 - 2\beta x = 0$$

which correspond to a system of geodesics through a point. In this case, however, the point is not a real point of S.

A system of circles with the centers on ox and passing through a point on the line $y = k$, $0 < k < C$ envelops a unicursal quartic of the form,

$$Ay^2 + A_1 x^2 + A_2 x^2 y^2 + 2A_3 x^2 y + 2A_4 xy^2 + 2A_5 xy = 0$$

This system of circles corresponds to a system of geodesics through a real point and the quartic curve to the geodesic envelop

$$e^{-2u/c}(A + A_2 v^2 + 2A_4 v) + e^{-u/c}(2A_3 C^{-1} v^2 + 2A_5 C^{-1} v) + (A_1 C^2) v^2 = 0$$

In this case the circles have a second common point on the line $y = -k$ so that the quartic envelope (which in this case is imaginary), having four nodes, breaks up into two circles which are themselves curves of the system and therefore correspond to the geodesics of the surface.

The orthogonal systems of circles,

$$x^2 + y^2 - 2\beta x \pm b^2 = 0$$

$$x^2 + (y - h)^2 = h^2 \pm b^2$$

having the radical axis correspond to the geodesics

$$v^2 + C^2 e^{-2u/c} - 2\beta v \pm b^2 = 0$$

and their orthogonal geodesic circles

$$v^2 + C^2 e^{-2u/c} - 2hCe^{-u/c} \pm b^2 = 0$$

These may be such that the limiting points of the circles are real and distinct, coincident or imaginary. It is interesting to note that this system of circles, which in so many problems in applied mathematics represents lines of *flow* and equipotential lines may be mapped conformally on the pseudosphere in such a way that the lines of flow and the equipotential lines are the geodesics of a system and their orthogonal geodesic circles.

Another straight line representation of the geodesic lines of the surface S.

If we project stereographically upon the sphere

$$\xi^2 + \eta^2 + (\zeta - 1/2)^2 = 1/4$$

whose south pole is the point (0, 0, 0) and whose north pole is the point (0, 0, 1), the circles given by the transformation $v = x$, $Ce^{-u/c} = y$ we shall have the upper part of the xy—plane represented conformally upon the hemisphere Lbd — C. The x—axis goes into the great circle Lbd and the

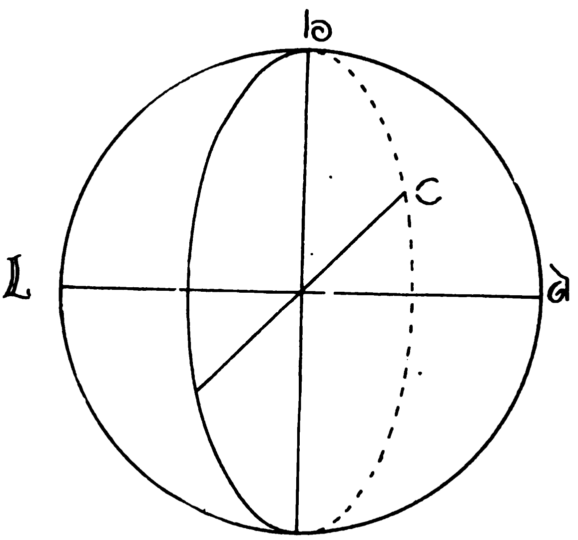



Fig. 1.

circles at right angles to o—x go into circles at right angles to Lbd.

If now we project orthogonally upon the plane Lbd we shall have the representation in question as chords of Lbd. Since $\xi\ \eta\ \zeta$ are the co-ordinates of the sphere we get as the equations of transformation from the plane to the sphere,

$$x = (\xi)/(1 - \zeta)$$
$$y = (\eta)/(1 - \zeta)$$

This gives for the circle

$$x^2 + y^2 - 2\beta x + \beta^2 - C^2\alpha^2 = 0$$

the plane

$$(1 - \beta^2 + C^2\alpha^2)\zeta - 2\beta\xi + \beta^2 - C^2\alpha^2 = 0$$

which is independent of $\eta$. It therefore represents the trace of the plane on the plane $\eta = 0$ and hence the required straight line in the $\xi\ \zeta$—plane.

The equations of transformation from the plane xy to the plane $\xi\zeta$ —plane are,

$$x = (\xi)/(1-\zeta)$$
$$y = ((\zeta(1-\zeta)) - (\xi^2))/(1-\zeta)^2)^{1/2}$$

and the equations of transformation from the pseudosphere to this plane are,

$$v^2 + C^2e^{-2u/c} = (\zeta)/(1-\zeta)$$
$$v = (\xi)/(1-\zeta)$$

### Discussion of the Transformation.

The entire upper part of the xy—plane is represented inside the circle $\xi^2 + \zeta^2 - \zeta = 0$

The circles $x^2 + y^2 - 2\beta x + \beta^2 - C^2\alpha^2 = 0$ become the straight lines

$$(\alpha^2 - \beta^2\alpha^2 + C^2)\zeta - 2\beta\alpha^2\xi + \beta^2\alpha^2 - C^2 = 0$$

The straight lines $y = k$ go into a sheaf of conics,

$$(k^2 + 1)\zeta^2 - (2k^2 + 1)\zeta + \xi^2 + k^2 = 0$$ through the point (0, 1). And since $-(k^2 + 1)$ is always negative the conics are all ellipses. The real part of the pseudosphere is therefore represented in the area included between the ellipses corresponding to the lines $y = C$ and $y = C/e$.

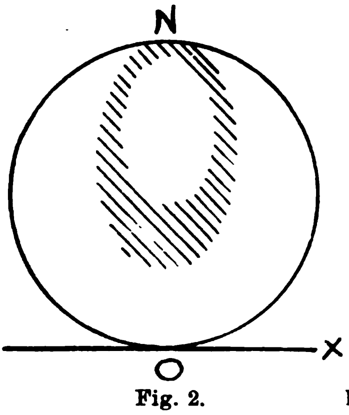


Fig. 2.

All the ellipses are tangent to the circle at the point (0, 1) and have their foci on the $\zeta$—axis. The circles concentric at the origin become the lines $\zeta$ = constant, chords parallel to the $\xi$—axis. The system of circles with centers on o—x and passing through the point a,b goes over into the system of straight lines through the point

$$\xi = (a)/(a^2 + b^2 + 1)$$
$$\zeta = (a^2 + b^2)/(a^2 + b^2 + 1)$$

Two such systems properly related and having the point (a,b) on the same line $y = b$ go over into the two projectively related sheaves of lines whose corresponding rays intersect on the conic corresponding to $y = b$. In particular, in case the points (a,b) are on the x—axis the conic becomes the circle o—b and the corresponding rays are at right angles. Circles with the centers on the x—axis and of equal radii go over into the straight lines enveloping an ellipse. The line $x = 0$ goes into $\xi = 0$ the points being moved along the line. The origin is the fixed point of transformation.

### ASYMPTOTIC LINES ON S.

The asymptotic lines on the surface are defined by the equation

$$D\,du^2 + .2D'du.dv + D''dv^2 = 0 \qquad \text{(See Note 1)} \quad \ldots\ldots(12)$$

This becomes for the surface S,

$$C + (C^2 - e^{2u/c})^{1/2} = e^{u/c}\,e(\pm v + \beta) \qquad \ldots\ldots(13)$$

and by (8) becomes in the x—y plane

$$y = -(y^2 - 1)^{1/2} + e(\pm x + \beta) \qquad \ldots\ldots(14)$$

### LOXODROMIC LINES ON S.

The differential equation of the loxodromic lines of a surface are given *by

$$((E)^{1/2}/(G)^{1/2})\ .\ (du/dv) = \tan\alpha \qquad \ldots\ldots(15)$$

Where $\alpha$ is the constant angle which the curves make with the curves $v =$ constant. For S (15) becomes,

$$(Cdu/u^2) = \pm \tan\alpha\ .dv.$$

Hence $\tan\alpha\ .uv + k_1u + C = 0$

This by the relation $u = e^{u'/c}$ becomes,

$$\tan\alpha\ .e^{u/c}\,v + k_1e^{u/c} + C = 0 \qquad \ldots\ldots(17)$$

which by (8) gives,

$$y = -\tan\alpha\ .x - k_1 \qquad \ldots\ldots(18)$$

This is a system of straight lines parallel to the line

$$y = -\tan\alpha\ .x$$

and so a system of lines making a constant angle with the lines $x =$ constant. And this is as it should be since the geodesic lines $v =$ constant go over into the lines $x =$ constant by the same transformation.

By selecting lines from different systems of loxodromic lines we may envelop any geodesic except the meridians. This may be seen by changing (17) to the form,

$$x\sin\alpha + y\cos\alpha + k_1\cos\alpha = 0$$

Where if $k_1$ and $\cos\alpha$ change so that $k_1\cos\alpha =$ constant we get a system of lines enveloping a circle with the centers at the origin. This corresponds to the loxodromic lines on the surface enveloping a geodesic.

*Bianchi, p. 109.

## CHAPTER II.

### Lines on the Syntractrix of Revolution.

Taking the equation of the syntractrix in the form,

$$x = (d^2 - y^2)^{1/2} + C\cosh^{-1}(d/y) \qquad \ldots\ldots(19)$$

the surface S is given by,

$$\left.\begin{aligned} x &= u\cos v \\ y &= u\sin v \\ z &= -(d^2 - u^2)^{1/2} + C\cosh^{-1}(d/u) \end{aligned}\right\} \ldots\ldots(20)$$

or we may transform the equation of the tractrix by

$$\left.\begin{aligned} y &= (C/d)y_1 \\ x &= x_1 + ((d - C)/d)(d^2 - y_1^2)^{1/2} \end{aligned}\right\} \ldots\ldots(21)$$

Giving as the relation between the surfaces S and $S_1$,

$$u = (c/d)u_1$$
$$v = v_1$$

In this work C represents the length of the tangents to the tractrix and d the constant distance taken on these tangents to get the syntractrix. Hence d = constant.C

We get for the fundamental qualities:

$E_1 = (u^2 - Cd)^2/(u^2(d^2 - u^2)) + 1$, $F_1 = 0$, $G_1 = u^2$ and

$D_1 - (u^2(d^2 - 2Cd) + Cd^3)/(u(d^2 - u^2)^{3/2})$

$$D'_1 = 0\ ,\ D''_1 = (u(u^2 - Cd))/(d^2 - u^2)^{1/2} \qquad \ldots\ldots(22)$$

$K_1 = ((u^2 - cd)(u^2(d^2 - 2Cd) + Cd^3))/((d^2 - u^2)(u^2(d^2 \quad 2cd) + C^2d^2)$

(Above equation is number 23 and is the equation of the Gaussian curvature.)

When C = d , (23) becomes $-1$ or the curvature of the pseudosphere. When $C = d/2, K_1$ becomes $(2u^2 - d^2)/(d^2 - u^2)$

Since for the surface $d \geqq u$ the denominator is always positive and the numerator is positive or negative according as

$$2u^2 - d^2 \gtrless 0$$

That is, according as $u > (d/(2)^{1/2})$ and $u < -(d)/((2)^{1/2})$ or $-(d/((2)^{1/2})$ $< u < d/((2)^{1/2})$ . For $u = \pm d/((2)^{1/2})$ , $K_1 = 0$. This means that for

the particular surface $S_1$ defined by $d = 2C$ the Gaussian curvature is zero for the circles u = constant, given by taking the distance d on the tangent whose inclination to the z—axis is $\pi/4$ or $(3\pi)/4$. Tangents to the tractrix whose inclination to the z axis is something between $\pi/4$ and $(3\pi)/4$ give the curves u = constant along which the surface have a negative curvature.

When $C$ $d/2$ we have from (23) $K_1$ positive, negative or zero according as $(u^2 - cd) = 0$. But $C < d/2$ gives $Cd < d^2/2$, so that $u^2(Cd < d^2/2$ is the condition for the positive curvature. The curvature is zero or negative when $u^2 = cd$ $d^2/2\,(u^2(d^2 - 2Cd) + Cd^3 = 0$ giving the imaginary values for $u$). This shows that the tangent line to the tractrix which gives the parabolic circle has a different slope than in the case where $d = 2C$, since in this case $u/d < (2)^{1/2}/2$, i. e. $\sin 0 < (2)^{1/2}/2$.

When $d < 2C$ we might consider three cases viz., $C < d < 2C$, $C = d$ or $C > d$. It will only be noted here that when $C = d$ the surface $S^1$ is the same as the surface $S$ and $K^1$ is therefore $-1$.

In any case $u^{2\prime} - Cd = 0$ gives the valves of $u$ for which the tangent line to the curve $C$ is parallel to the $u$—axis.

### Geodesic Lines on $S^1$.

Using the method of the calculus of variations as outlined in Chapter I we get for the geodesic lines on the syntractrix of revolution,

$$F_{v'} = (u^2dv)/(E_1du^2 + G_1dv^2)^{1/2} = r$$

Here two cases may be considered according as

$$r = 0 \text{ or } r \neq 0$$

(1) When $r = 0$, then either $u = 0$ or $dv = 0$. But $u \neq 0$, hence $dv = 0$ and therefore $v =$ constant. That is the meridians are geodesic lines,

(2) When $r \neq 0$ we have

$$dv = ((r\,u^2)(u^2(d^2 - 2Cd) + C^2d^2)^{1/2}/((d^2 - u^2)(r^2 - u^2))^{1/2})dv$$

(The above equation is number 24.)

To reduce this expression on the right hand side to a convenient form substitute,

$$u^2(d^2 - 2Cd) + C^2d^2 = (C^2d^2t^2)/(t^2 - 1) \qquad \ldots\ldots(25)$$

This may be written $u^2k + k_1 = (k^1t^2)/(t^2 - 1)$ for convenience then,

$$dv = (-k^{3/2}r\,t^2\,dt)/((kr^2 + k_1)^{1/2}.\,(kd^2 + k_1)^{1/2}((at^2-1).(bt^2 - 1))^{1/2}) \qquad \ldots\ldots(26)$$

Where $a = (kd^2)/(kd^2 + k_1)$ and $b = (kr^2)/(kr^2 + k_1)$

When $r \neq 0$ we may consider two cases

When $r = d$ and $r \neq d$

When $r = d$ equation (26) becomes,

$$dv = (-k^{3/2}d_1dt)/(kd^2 + k_1(at^2 - 1)) \qquad \ldots\ldots(27)$$

so that

$$v = (-k^{3/2}d/(a(kd^2 + k_1))(t + 1/2(a)^{1/2}\log((a)^{1/2}t-1)/((a)^{1/2}t+1)) + \delta \qquad \ldots\ldots(28)$$

Eliminating "t" between (25) and (28) we have the the geodesic lines for $r = d$ given by

$$v = \frac{-(u^2k + k_1)^{1/2}}{u.d} - \frac{(kd^2 + k_1)^{1/2}}{2d^2}\log\frac{d(u^2k+k_1)^{1/2}-u(kd^2+k_1)^{1/2}}{d(u^2k+k_1)^{1/2}+u(kd^2+k_1)^{1/2}} + \delta$$

(The above equation is equation 29.)

When $r = d$ (26) gives rise to an elliptic integral for the reduction of which we recall from the general theory of elliptic integrals. (See Note 1.)

$$R(x) = Ax^4 + 4Bx^3 + 6Cx^2 + 4B'x + A'$$

$$g_2 = AA' - 4BB' + 3C^2$$

$$g_3 = ACA' + 2BCB' - A'B^2\ AB'^2 - C^3$$

In this case we have,

$$R(t) = abt^4 - (a+b)t^2 + 1$$

$$g_2 = ab + (a+b)^2/12$$

$$g_3 = (-ab(a+b))/6 + (a+b)^3/216$$

We also have

$$R'(t) = 4abt^3 - 2(a+b)t$$

$$R''(t) = 12abt^2 - 2(a+b)$$

Substituting in (26)

$$t = \epsilon + (1/4\ R'(\epsilon))/(pu - 1/24\ R''(\epsilon)) \quad \text{(See Note 2)} \ldots\ldots(30)$$

Where $\epsilon$ is one of the roots of $R(t) = 0$. In this case take $\epsilon = 1/(a)^{1/2}$ then,

$$R'(1/(a)^{1/2}) = (2(b-a))/(a)^{1/2}$$

$$R''(1/(a)^{1/2}) = 2(b - a)$$

So that (30) may be written,

$$t = 1/(a)^{1/2} + ((b-a)/(2(a)^{1/2}))/(pu - pv)$$

when $pv = (1/12)(5b - a)$ and therefore

$$abt^2 = b + (b(b-a))/(pu - pv) + (1/4)((b(b-a)^2)/(pu - pv)^2$$

Recalling now that,

$$(p'v)^2 = 4p^3v - g_2pv - g_3 \qquad \ldots\ldots(31)$$

$$p''v = 6pv - 1/2\ g_2 \qquad \ldots\ldots(32)$$

and also,

$$(p'v)^2/(pu - pv)^2 + (pu - p''v)/(pv) =$$

$$p(u + v) + p(u - v) - 2pv \qquad \ldots\ldots(33)$$

NOTE 1.—Klein, Modular, Functionen, Vol. I, p. 15.

NOTE 2.—Enneper, Elliptische Functionen, p. 30.

We get in the present case,

$$(p'v)^2 = ((b(b-a)^2)/4$$

$$p''v = b(b-a)$$

Equation (26) may be written,

$$v = ((-k^3/{}^2r\ )/((ab(kr^2+k_1)^{1/2})(kd^2+k_1\ \cdot,\ ^{=})\ .$$

$$\int(b = p(u+v) + p(u + v) + 2pv)bu + \delta$$

and so

$$v = K((1/6)(b-a)u + (\sigma'/\sigma)(u + v) + (\sigma'/\sigma)(u + v)) + \delta \qquad ......(34)$$

where $K = (\ -(k)^{1/2})/(d(ab)^{1/2})$

The geodesic lines on S are then given by means of t,

$$u^2k + k_1 = (k_1t^2)/(t^2 - 1)$$

$$v = K\ \phi(t) + \delta$$

where $\phi(t)$ is given in (34) and $u = p^{-1}((b-a)/(2(a)^{1/2}t - 2) + pv)$

$$v = p^{-1}((5/12)b - (a/12))$$

If (24) be put in the form

$$(du/dv) = (u^2/r)\ ((d^2 - u^2)(r^2 - u^2))^{1/2}/(u^2(d^2 - 2Cd) + C^2d^2)^{1/2}$$

it is seen at once that the equation is satisfied by the values u = constant. But from the geometric consideration it is evident that, in general, the circles u = constant are not geodesic lines since the normals to a geodesic line must also be normal to the surface. And from figures V and VI it is seen at once that this is only true for the circle $u = d$, where $d \gtrless C$, and for the trivial case $u = 0$ no matter what the value of d.

The geodesic lines on the surfaces $S_1$ may be studied if the surfaces are divided into classes according as $d \gtreqless 2C$.

In the case $d = 2C$ the general integral (26) takes the form,

$$v = \int((d^2r)/(2u))\ ((du)/((d^2 - u^2)(r^2 - u^2))$$

which when $u = 1/t$ may be written as

$$v = -\ (-d^2r)/2\int(t^2dt)/((d^2t^2 - 1)(r^2t^2 - 1)$$

Here $R(t) = d^2r^2\ t^4 - (d^2 + r^2)t^2 + 1$. It is evident that this is exactly the same as the R(t) of the general case if we replace $d^2$ by a and $r^2$ by b. Taking note of this we may write the geodesic lines in terms of t

$$u = 1/t$$

$$v = (-1/2r)\ (1/6\ (r^2-d^2)u + (\sigma'/\sigma\ (u+v) + (\sigma'/\sigma)(u-v)) + \delta$$

where $u = p^{-1}((r^2-d^2)/(2dt-2) + pv)$ and $v + p^{-1}(5\ ^2-d^2)/(12)$. In this case the geodesics are real for all values of r.

In particular when $d = 2C$ and $r = d$ (29) becomes

$$v = \overline{+}\ (d/2u) + (1/4) \log (d-u)/(d+u) + \delta$$

For the purpose of illustration let $d = 1$ then (35) becomes

$$v = \mp (d/2u) + (1/4) \log (1-u)/(1+u) - \delta$$

And since $\delta$ is an added constant we may without loss of generality let $\delta + 0$.

This particular geodesic line has been drawn in figure 3. It is to be noted that the line winds around the surface as it approaches smaller values, and then again winds around approaching the circle $u = 1$. The lines $r = d = 1$ are all similar to this one and may be obtained by giving different values to $\delta$.

When $d > 2C$, $k = (d^2 - 2Cd)$ is positive and $ab$ is positive and since $k_1 = C^2d^2$ is always positive and we have $K$ always real so that the geodesic lines on the surface $S_1$ defined by $d > 2C$ are all real.

When $d < 2C$, $k = (d^2 - 2Cd)$ is negative and $ab$ is positive or negative according as $r^2 \lessgtr |k_1/k|$ or $\lessgtr |C^2d^2)/(d^2 - 2Cd|$ So that on the surface $S_1$ defined by $d < 2C$, $K$ will be real or imaginary according as $r^2 \gtrless (k_1/k)$. Hence the geodesic lines on such surfaces become imaginary lines when $r^2 > |k_1/k|$, that is when $r > |k_1/k|^{1/2}$ and $r < -|k_1/k|^{2/2}$.

### Asymptotic Lines on $S_1$.

From the general equation of the asymptotic lines on a surface we get for the asymptotic lines on $S_1$,

$$(u^2(d^2 - 2Cd) + Cd^3)^{1/2}/(u((Cd - u^2)(d^2 - u^2)^{1/2}))\, du = \pm dv$$

(The above equation is number 37).

The substitution of $u^2(d^2 + 2Cd)\quad Cd^3 = 1/t^2$ reduces (37) to the form,

$$(-kdt)/((1-k_1t^2)((at^2 - 1)(bt^2 - 1))^{1/2} = \pm dv.$$

Where $k = d^2 - 2Cd$, $k_1 = Cd^3$, $a = Cdk + k_1$, $b = d^2k + k_1$.

In the particular case when $d = 2C$ (37) becomes

$$((d^2)/(u((d^2 - 2u^2)(d^2 - u^2))^{1/2}))\, .\, du = + dv$$

Which when $u = 1/t$ reduces to

$$(-d^2t\, .\, dt)/((d^2t^2 - 2)(d^2t^2 - 1))^{1/2} = \pm dv \qquad \ldots\ldots(39)$$

Here
$$R(t) = d^4t^4 - 3d^2t^2 + 2$$
$$R'(t) = 4d^4t^3 - 6d^2t$$
$$R''(t) = 12d^4t^2 - 6d^2$$
$$g_2 = (11/4)d^4$$
$$g_3 = (9/8)d^6$$

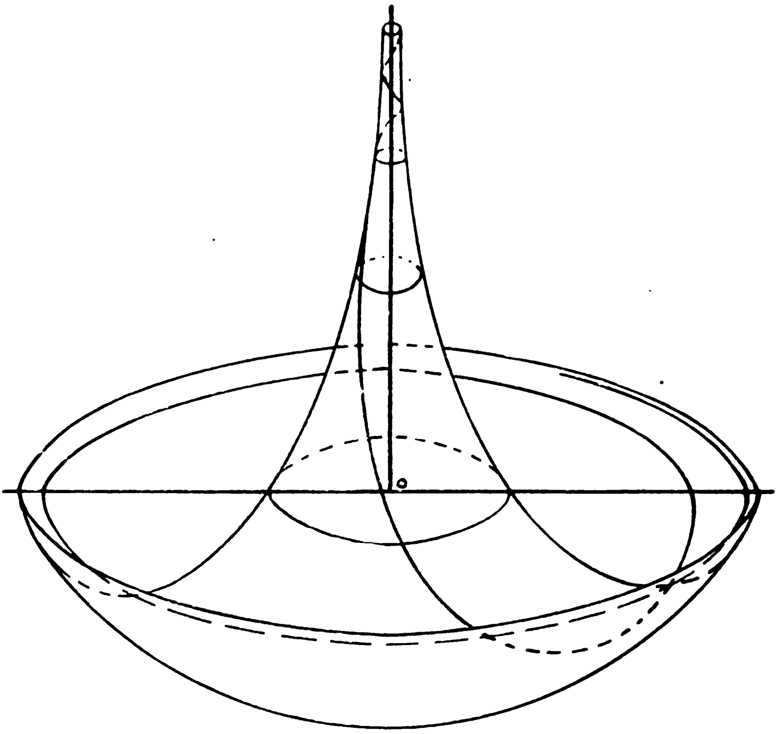


Fig. 9

To reduce (39) substitute

$$t = (a + (1\ 4R'(a))\ (pu - (1\ 24)R''(a)) \qquad \ldots\ldots (40)$$

Where a is a root of R(t). In this case take $a = 1\ d$. Then equation (40) may be written,

$$t - ((1\ d) + ((-d\ 2)\ (pu - pv)) \qquad \ldots\ldots (41)$$

where $pv = d^2\ 4$

Since $(p'v)^2 = 4p^3v - g_2pv - g_3 - ((2)^1\ {}^2)\ 2)d^3$ and $(-p'v)\cdot pu - pv) = (\sigma'\ \sigma)(u + v) - (\sigma'\ \sigma)(u - v) - 2(\sigma'\ \sigma)\ (v)$ (Note 1) we have, remembering the relation $(dt\ du) = (R(t))^1\ {}^2 + v = (-1/((2)^1\ {}^2) \int ((2)^1\ {}^2d + \sigma'$

$-(u + v)(\sigma'\ \sigma)(u - v) - 2(\sigma'\ \sigma)v)du + \delta' + v = (-(d-(2)^1\ {}^2(\sigma'/\sigma)(v)u)$
$\sigma$
$- ((2)^1\ {}^2)\ 2 \log (\sigma(u - v)\ \sigma(u + v) + \delta'$

(The above is equation 42.)

NOTE: Schwarz. Formeln der elliptschen Functionen, p. 13.

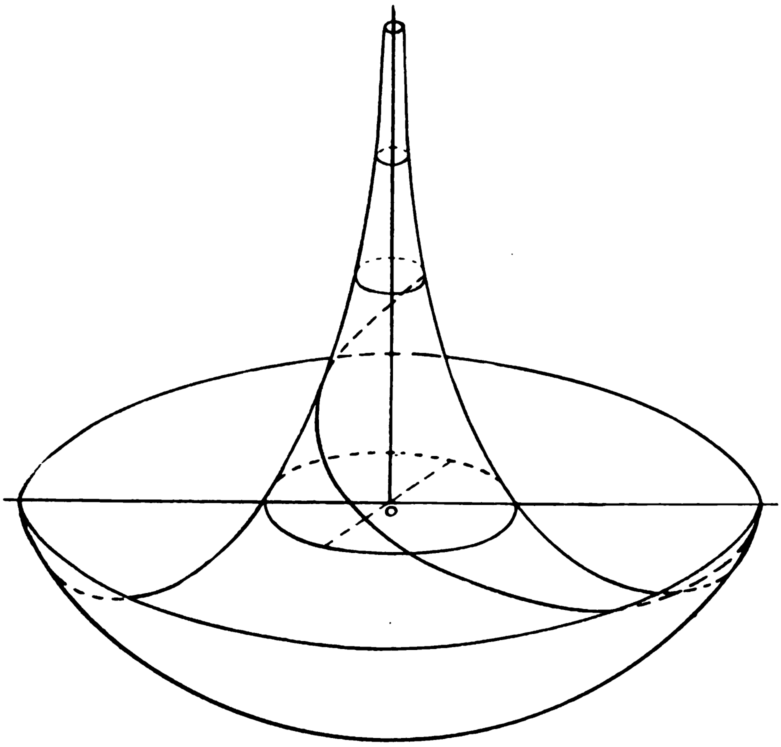


FIG. – 4

The asymptotic lines in this case are then given by the equations,

$$u = 1/t$$

$$v = \Psi(t) + \gamma$$

where $\Psi(t)$ is given in (42) & $u = p^{-1}((3d^2 - td^3)/(4 - 4td))$ $v = p^{-1}(d^2/4)$

## LOXODROMIC LINES ON $S^1$.

The general equations for the loxodromic lines on a surface $((E)^{1/2}/(G)^{1/2})$, $du = \pm \tan \alpha\, dv$ becomes in the case of $S_1$ $((u^2(d^2-2Cd) + C^2d^2)^{1/2})/(u^2(d^2-u^2)^{1/2}))du = \pm \tan \alpha \cdot dv$ which by the substitution $u^2(d^2 - 2Cd) + C^2d^2 = (C^2d^2t^2)/(t^2 - 1)$ reduces to the form,

$$((2C - d)(t^2dt))/((t^2 - 1)((d^2 - 2Cd)t^2 - (d - C)^2)^{1/2} = \pm \tan \alpha \cdot dv.$$

(The above equation is number 43.) This may be put in the form,

$$((2C - d)/(k_2)^{1/2}) \cdot ((t^2Ct)/((k^2t^4) - (k^2 + 1)t^2 + 1)^{1/2} = \pm \tan \alpha \cdot dv.$$

(The above is equation 44.)

Where $k_2 = (d-C)^2$ and $k^2 = (d^2 - 2Cd)/(d-C)^2$

Here,

$$R(t) = k^2t^4 - (k^2+1)t^2 + 1$$
$$R'(t) = 4k^2t^3 - 2(k^2+1)t$$
$$R''(t) = 12k^2t^2 - 2(k^2+1)$$
$$g_2 = (1/12)(1 + 14k^2 + k^4)$$
$$g_3 = ((1+k^2)/(216))(1 - 34k^2 + k^4)$$

(44) may be reduced by the substitution,

$$t = 1 + ((k^2-1)/2)(pu - pv) \qquad \ldots\ldots(45)$$

Where $\quad pv = (1/12)(5k^2-1)$

Then $k^2t^2 = k^2 + (k^2(k^2-1))(pu - p\underline{v}) + ((k^2/4)(k^2-1)^2)/(pu - pv)^2$ and since $dt/du = (R(t))^{1/2}$ we get by using (31), (32) and (33) $\pm \tan \propto \cdot v - (2C-d)/((k_2)^{1/2}(k^2))((1/6)(k^2+1)\underline{u} + (\delta'/\delta)(\underline{u}+v) + (\delta'/\delta)(u-v)) + \delta'' \qquad \ldots\ldots(46)$

We have then the loxodromic lines on the surface $S_1$ given in terms of t by the equations,

$$u^2(d^2-2Cd) + C^2d^2 = (C^2d^2t^2)/(t^2-1)$$
$$v = \varphi(t) + \delta''$$

where $\varphi(t)$ is given in (46) and $\underline{u} = p^{-1}((2/(k^2-1)(t-1)) + p\underline{v})$ $\underline{v} = p^{-1}((5k^2-1)/(12))$

Since $k_2 = (d-c)^2$ is always positive it is to be noted that $\varphi(t)$ is always real.

In particular when $d = 2C$ the equation, the general equation for the loxodromic lines reduces to,

$$((d^2/2)/(u^2(d^2-u^2)^{1/2}))\,du = \pm \tan\propto \cdot dv \qquad \ldots\ldots(47)$$

and therefore

$$(-(d^2-u^2)^{1/2}/2u) = \pm \tan\propto \cdot v + \delta'' \qquad \ldots\ldots(47a)$$

and these by the substitution $((d^2-u^2)^{1/2}/2u) = y$, $v = x$ are given in the x-y plane by the straight lines,

$$y = \pm \tan\propto x + \delta'' \qquad \ldots\ldots(48)$$

But this is the system of lines into which the loxodromic lines of the pseudosphere may be transformed. Hence the loxodromic lines on S and $S_1$ (when $d = 2C$) may be represented by the same set of straight lines in the plane.

Suppose $d = 2C = 1$ and $\delta'' = 0$ and the $\tan\propto = 1$. Then $47_a$ becomes

$$(-(d^2-u^2)^{1/2})/(2u) = \pm v.$$

This gives a line on the surface from the point $(u_1, v_1) = (1, 0)$ making an angle of 45° with the lines $v =$ constant. The line winds about the surface as shown in figure IV.

The surfaces $S_1$ might have been classified according as $d = C$. The advantages of such a classification are not apparent in the analytical work and can only be seen from the geometry of the surface or the generating curve. In the work as presented the pseudosphere comes in as a special case of the surfaces $S_1$ when $d$ $2C$, while if the classification had been made as above indicated the pseudosphere $d = C$ would be the dividing surface in the classification. On the whole I think the classification adopted is to be preferred. See figures V & VI for the different types of generating curves $d$ $C$, $d = C$ and $d$ $C$. The cut for $d$ $C$ is not given, but a general idea of the curve may be obtained by leaving off the loop in figure V.

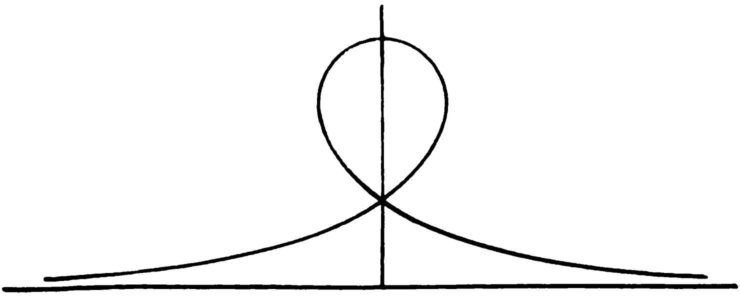


FIG.- 5

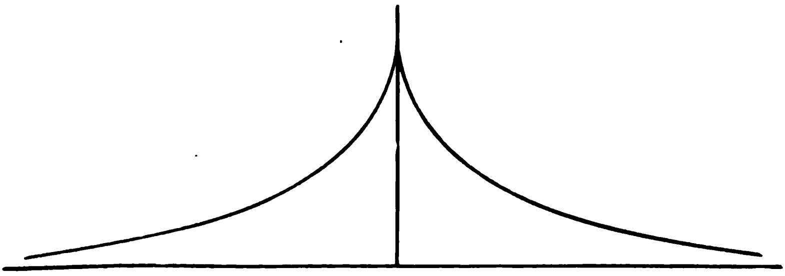


FIG.- 6

# INDEX.

# PROCEEDINGS

OF THE

# Indiana Academy of Science

## 1908

EDITOR . . . . . . . . . . . . . . H. L. BRUNER

INDIANAPOLIS, IND.
1909

INDIANAPOLIS
WM. B. BURFORD, PRINTER
1909

THE STATE OF INDIANA,
EXECUTIVE DEPARTMENT,
April 19, 1909.

Received by the Governor, examined and referred to the Auditor of State for verification of the financial statement.

---

OFFICE OF AUDITOR OF STATE,
INDIANAPOLIS, April 28, 1909.

The within report (no financial statement) has been examined and found correct.

JOHN O. BILLHEIMER,
*Auditor of State.*

---

APRIL 28, 1909.

Returned by the Auditor of State, with above certificate, and transmitted to Secretary of State for publication, upon the order of the Board of Commissioners of Public Printing and Binding.

MARK THISTLETHWAITE,
*Secretary to the Governor.*

---

Filed in the office of the Secretary of State of the State of Indiana, April 29, 1909.

FRED A. SIMS,
*Secretary of State.*

---

Received the within report and delivered to the printer April 29, 1909.

A. E. BUTLER,
*Clerk Printing Board.*

# TABLE OF CONTENTS.

# AN ACT TO PROVIDE FOR THE PUBLICATION OF THE REPORTS AND PAPERS OF THE INDIANA ACADEMY OF SCIENCE.

[Approved March 11, 1895.]

Preamble.

WHEREAS, The Indiana Academy of Science, a chartered scientific association, has embodied in its constitution a provision that it will, upon the request of the Governor, or of the several departments of the State government, through the Governor, and through its council as an advisory body, assist in the direction and execution of any investigation within its province, without pecuniary gain to the Academy, provided only that the necessary expenses of such investigation are borne by the State; and,

WHEREAS, The reports of the meetings of said Academy, with the several papers read before it, have very great educational, industrial and economic value, and should be preserved in permanent form; and

WHEREAS, The Constitution of the State makes it the duty of the General Assembly to encourage by all suitable means intellectual, scientific and agricultural improvement; therefore,

**Publication of the Reports of the Indiana Academy of Science.**

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana*, That hereafter the annual reports of the meetings of the Indiana Academy of Science, beginning with the report for the year 1894, including all papers of scientific or economic value, presented at such meetings, after they shall have been edited and prepared for publication as hereinafter provided, shall be published by and under the direction of the Commissioners of Public Printing and Binding.

**Editing Reports.**

SEC. 2. Said reports shall be edited and prepared for publication without expense to the State, by a corps of editors to be selected and appointed by the Indiana Academy of Science, who shall not, by reason of such services, have any claim against the State for compensation. The form, style of binding, paper, typography and manner and extent of illustration of such reports shall be determined by the editors, subject to the approval of the Commissioners of Public Printing and Stationery. Not less than 1,500 nor more than 3,000 copies of each of said

**Number of printed Reports.**

reports shall be published, the size of the edition within said limits to be determined by the concurrent action of the editors and the Commissioners of Public Printing and Stationery: *Provided*, That not to exceed six hundred dollars ($600) shall be expended for such publication in any one year, and not to extend beyond 1896: *Provided*, That no sums shall be deemed to be appropriated for the year 1894.

**Proviso.**

**Disposition of Reports.**

SEC. 3. All except three hundred copies of each volume of said reports shall be placed in the custody of the State Librarian, who shall furnish one copy thereof to each public library in the State, one copy to each university, college or normal school in the State, one copy to each high school in the State having a library, which shall make application therefor, and one copy to such other institutions, societies or persons as may be designated by the Academy through its editors or its council. The remaining three hundred copies shall be turned over to the Academy to be disposed of as it may determine. In order to provide for the preservation of the same it shall be the duty of the Custodian of the State House to provide and place at the disposal of the Academy one of the unoccupied rooms of the State House, to be designated as the office of the Indiana Academy of Science, wherein said copies of said reports belonging to the Academy, together with the original manuscripts, drawings, etc., thereof can be safely kept, and he shall also equip the same with the necessary shelving and furniture.

**Emergency.**

SEC. 4. An emergency is hereby declared to exist for the immediate taking effect of this act, and it shall therefore take effect and be in force from and after its passage.

## AN ACT FOR THE PROTECTION OF BIRDS, THEIR NESTS AND EGGS.

SECTION 602. It shall be unlawful for any person to kill, trap or possess any wild bird, or to purchase or offer the same for sale, or to destroy the nests or the eggs of any wild bird except as otherwise provided in this section. But this section shall not apply to the following named game birds: The Anatidæ, commonly called swans, geese, brant, river and sea duck; the Rallidæ, commonly known as rails, coots, mudhens, and gallinules; the Limicolæ, commonly known as shore birds, plovers, surf birds, snipe, woodcock, sandpipers, tatlers and curlews; nor to English or European house sparrows, crows, hawks, or other birds of prey. Nor shall this section apply to any person taking birds or their nests or eggs for scientific purposes under permit, as provided in the next section. Any person violating the provisions of this section shall, upon conviction, be fined not less than ten dollars nor more than fifty dollars.

Birds.

SEC. 603. Permits may be granted by the Commissioner of Fisheries and Game to any properly accredited person, permitting the holder thereof to collect birds, their nests or eggs for strictly scientific purposes. In order to obtain such permit the applicant for the same must present to said Commissioner written testimonials from two well-known scientific men certifying to the good character and fitness of said applicant to be entrusted with such privilege, and pay to said Board one dollar therefor, and file with him a properly executed bond in the sum of two hundred dollars, payable to the State of Indiana, conditioned that he will obey the terms of such permit, and signed by at least two responsible citizens of the State as sureties. The bond may be forfeited and the permit revoked upon proof to the satisfaction of such Commissioner that the holder of such permit has killed any bird or taken the nests or eggs of any bird for any other purpose than that named in this section.

# Indiana Academy of Science.

## OFFICERS, 1908-1909.

PRESIDENT
A. L. FOLEY.

VICE-PRESIDENT
P. N. EVANS.

SECRETARY
JAMES H. RANSOM.

ASSISTANT SECRETARY
A. J. BIGNEY.

PRESS SECRETARY
GEORGE A. ABBOTT.

TREASURER
WILLIAM A. MCBETH.

EXECUTIVE COMMITTEE

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|---|---|---|
| FOLEY, | CARL L. MEES, | A. W. BUTLER, |
| EVANS, | W. S. BLATCHLEY, | W. A. NOYES, |
| RANSOM, | H. W. WILEY, | J. C. ARTHUR, |
| BIGNEY, | M. B. THOMAS, | O. P. HAY, |
| ABBOTT, | D. W. DENNIS, | T. C. MENDENHALL, |
| . MCBETH, | C. H. EIGENMANN, | J. C. BRANNER, |
| N CULBERTSON, | C. A. WALDO, | J. P. D. JOHN, |
| . MOTTIER, | THOMAS GRAY, | J. M. COULTER, |
| RT HESSLER, | STANLEY COULTER, | D. S. JORDAN, |
| S. WRIGHT, | | |

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NY ........ J. C. ARTHUR.
IYOLOGY ........ C. H. EIGENMANN.
ETOLOGY, IOLOGY, THOLOGY ........ A. W. BUTLER.
MOLOGY ........ W. S. BLATCHLEY

# COMMITTEES, 1908–1909.

**Program,**
W. J. Moenkhaus, H. L. Bruner, J. P. Naylor.

**Membership,**
R. Hessler, D. Rothrock, P. N. Evans.

**Nominations,**
J. S. Wright, S. Burrage, D. M. Mottier.

**Auditing,**
W. J. Moenkhaus, W. A. Cogshall, E. G. Mahin.

**State Library,**
J. S. Wright, W. S. Blatchley, A. W. Butler, G. W. Benton.

**Restriction of Weeds and Diseases,**
R. Hessler, J. N. Hurty, A. W. Butler, S. Coulter, D. M. Mottier.

**Directors of Biological Survey,**
Stanley Coulter, C. R. Dryer, M. B. Thomas, C. H. Eigenmann, J. C. Arthur.

**Relations of the Academy to the State,**
R. W. McBride, M. B. Thomas, G. Culbertson, W. S. Blatchley.

**Distribution of the Proceedings,**
J. S. Wright, H. L. Bruner, G. W. Benton, R. E. Lyons, J. H. Ransom.

**Publication of Proceedings,**
H. L. Bruner, Editor, D. Bodine, D. M. Mottier.

# OFFICERS OF THE INDIANA ACADEMY OF SCIENCE.

| Years. | President. | Secretary. | Asst. Secretary. | Press Secretary. | Treasurer. |
|---|---|---|---|---|---|
| 1885–1886 | David S. Jordan | Amos W. Butler | | | O. P. Jenkins. |
| 1886–1887 | John M. Coulter | Amos W. Butler | | | O. P. Jenkins. |
| 1887–1888 | J. P. D. John | Amos W. Butler | | | O. P. Jenkins. |
| 1888–1889 | John C. Branner | Amos W. Butler | | | O. P. Jenkins. |
| 1889–1890 | T. C. Mendenhall | Amos W. Butler | | | O. P. Jenkins. |
| 1890–1891 | O. P. Hay | Amos W. Butler | | | O. P. Jenkins. |
| 1891–1892 | J. L. Campbell | Amos W. Butler | | | C. A. Waldo. |
| 1892–1893 | J. C. Arthur | Amos W. Butler | Stanley Coulter<br>W. W. Norman | | C. A. Waldo. |
| 1893–1894 | W. A. Noyes | C. A. Waldo | W. W. Norman | | W. P. Shannon. |
| 1894–1895 | A. W. Butler | John S. Wright | A. J. Bigney | | W. P. Shannon. |
| 1895–1896 | Stanley Coulter | John S. Wright | A. J. Bigney | | W. P. Shannon. |
| 1896–1897 | Thomas Gray | John S. Wright | A. J. Bigney | | W. P. Shannon. |
| 1897–1898 | C. A. Waldo | John S. Wright | A. J. Bigney | Geo. W. Benton | J. T. Scovell. |
| 1898–1899 | C. H. Eigenmann | John S. Wright | E. A. Schultze | Geo. W. Benton | J. T. Scovell. |
| 1899–1900 | D. W. Dennis | John S. Wright | E. A. Schultze | Geo. W. Benton | J. T. Scovell. |
| 1900–1901 | M. B. Thomas | John S. Wright | E. A. Schultze | Geo. W. Benton | J. T. Scovell. |
| 1901–1902 | Harvey W. Wiley | John S. Wright | Donaldson Bodine | Geo. W. Benton | J. T. Scovell. |
| 1902–1903 | W. S. Blatchley | John S. Wright | Donaldson Bodine | G. A. Abbott | W. A. McBeth. |
| 1903–1904 | C. L. Mees | John S. Wright | J. H. Ransom | G. A. Abbott | W. A. McBeth. |
| 1904–1905 | John S. Wright | Lynn B. McMullen | J. H. Ransom | G. A. Abbott | W. A. McBeth. |
| 1905–1906 | Robert Hessler | Lynn B. McMullen | J. H. Ransom | Charles R. Clark | W. A. McBeth. |
| 1906–1907 | D. M. Mottier | Lynn B. McMullen | J. H. Ransom | G. A. Abbott | W. A. McBeth. |
| 1907–1908 | Glenn Culbertson | J. H. Ransom | A. J. Bigney | G. A. Abbott | W. A. McBeth. |
| 1908–1909 | A. L. Foley | J. H. Ransom | A. J. Bigney | G. A. Abbott | W. A. McBeth. |

# CONSTITUTION.

## ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SEC. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science, to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other resources and riches of the State; to arrange and prepare for publication such reports of investigation and discussions as may further the aims and objects of the Academy as set forth in these articles.

Whereas, The State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or of one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

## ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident members or active members.

SEC. 2. Any person engaged in any department of scientific work, or in original research in any department of science, shall be eligible to active membership. Active members may be annual or life members. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars, and thereafter an annual fee of one dollar. Any person who shall at one time contribute

fifty dollars to the funds of this Academy may be elected a life member of the Academy, free of assessment. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Applications for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

SEC. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

## ARTICLE III.

SECTION 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a President, Vice-President, Secretary, Assistant Secretary, Press Secretary and Treasurer, who shall perform the duties usually pertaining to their respective offices, and in addition, with the ex-Presidents of the Academy, shall constitute an Executive Committee. The President shall, at each annual meeting, appoint two members to be a committee, which shall prepare the programs and have charge of the arrangements for all meetings for one year.

SEC. 2. The annual meeting of this Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the Executive Committee. There shall also be a summer meeting at such time and place as may be decided upon by the Executive Committee. Other meetings may be called at the discretion of the Executive Committee. The past Presidents, together with the officers and Executive Committee, shall constitute the council of the Academy, and

represent it in the transaction of any necessary business not especially provided for in this constitution, in the interim between general meetings.

SEC. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

## BY-LAWS.

1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The President shall deliver a public address on the morning of one of the days of the meeting at the expiration of his term of office.

3. The Press Secretary shall attend to the securing of proper newspaper reports of the meetings and assist the Secretary.

4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the President and countersigned by the Secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of business.

# MEMBERS.

## *FELLOWS.*

| | | |
|---|---|---|
| G. A. Abbott | *1908 | Indianapolis. |
| R. J. Aley | 1898 | Bloomington. |
| J. C. Arthur | 1894 | Lafayette. |
| J. W. Beede | 1906 | Bloomington. |
| George W. Benton | 1896 | Indianapolis. |
| A. J. Bigney | 1897 | Moore's Hill. |
| Katherine Golden Bitting | 1895 | Lafayette. |
| W. S. Blatchley | 1893 | Indianapolis. |
| Donaldson Bodine | 1899 | Crawfordsville. |
| H. L. Bruner | 1899 | Indianapolis. |
| Severance Burrage | 1898 | Lafayette. |
| A. W. Butler | 1893 | Indianapolis. |
| W. A. Cogshall | 1906 | Bloomington. |
| †Mel. T. Cook | 1902 | Newark, Del. |
| †John M. Coulter | 1893 | Chicago, Ill. |
| Stanley Coulter | 1893 | Lafayette. |
| U. O. Cox | 1908 | Terre Haute. |
| Glenn Culbertson | 1899 | Hanover. |
| E. R. Cumings | 1906 | Bloomington. |
| S. C. Davisson | 1908 | Bloomington. |
| D. W. Dennis | 1895 | Richmond. |
| C. R. Dryer | 1897 | Terre Haute. |
| C. H. Eigenmann | 1893 | Bloomington. |
| Percy Norton Evans | 1901 | West Lafayette. |
| A. L. Foley | 1897 | Bloomington. |
| M. J. Golden | 1899 | Lafayette. |
| †W. F. M. Goss | 1893 | Urbana, Ill. |
| Thomas Gray | 1893 | Terre Haute. |
| A. S. Hathaway | 1895 | Terre Haute. |
| W. K. Hatt | 1902 | Lafayette. |
| Robert Hessler | 1899 | Logansport. |

*Date of election.
†Non-resident.

| | | |
|---|---|---|
| †H. A. Huston | *1893 | Chicago, Ill. |
| Edwin S. Johonnatt | 1904 | Terre Haute. |
| Robert E. Lyons | 1896 | Bloomington. |
| W. A. McBeth | 1904 | Terre Haute. |
| V. F. Marsters | 1893 | Bloomington. |
| C. L. Mees | 1894 | Terre Haute. |
| †J. A. Miller | 1904 | Swarthmore, Pa. |
| W. J. Moenkhaus | 1901 | Bloomington. |
| D. M. Mottier | 1893 | Bloomington. |
| J. P. Naylor | 1903 | Greencastle. |
| †W. A. Noyes | 1893 | Champaign, Ill. |
| Rolla R. Ramsey | 1906 | Bloomington. |
| J. H. Ransom | 1902 | Lafayette. |
| L. J. Rettger | 1896 | Terre Haute. |
| David Rothrock | 1906 | Bloomington. |
| J. T. Scovell | 1894 | Terre Haute. |
| Albert Smith | 1908 | Lafayette. |
| †Alex Smith | 1893 | Chicago, Ill. |
| W. E. Stone | 1893 | Lafayette. |
| †Joseph Swain | 1898 | Swarthmore, Pa. |
| M. B. Thomas | 1893 | Crawfordsville. |
| †C. A. Waldo | 1893 | St. Louis, Mo. |
| †F. M. Webster | 1894 | Washington, D. C. |
| Jacob Westlund | 1904 | Lafayette. |
| †H. W. Wiley | 1895 | Washington, D. C. |
| W. W. Woollen | 1908 | Indianapolis. |
| John S. Wright | 1894 | Indianapolis. |

*Date of election.
†Non-resident.

## *NON-RESIDENT MEMBERS.*

| | |
|---|---|
| George H. Ashley | Charleston, S. C. |
| J. C. Branner | Stanford University, Cal. |
| M. A. Brannon | Grand Forks, N. D. |
| D. H. Campbell | Stanford University, Cal. |
| A. Wilmer Duff | Worcester, Mass. |
| B. W. Everman | Washington, D. C. |
| W. A. Fiske | Los Angeles, Cal. |

| | |
|---|---|
| C. W. Garrett | Pittsburg, Pa. |
| Charles H. Gilbert | Stanford University, Cal. |
| C. W. Green | Columbia, Mo. |
| C. W. Hargitt | Syracuse, N. Y. |
| O. P. Hay | New York City. |
| Edward Hughes | Stockton, Cal. |
| O. P. Jenkins | Stanford University, Cal. |
| D. S. Jordan | Stanford University, Cal. |
| J. S. Kingsley | Tufts College, Mass. |
| D. T. MacDougal | Tuscon, Arizona. |
| L. B. McMullen | Valley City, N. D. |
| T. C. Mendenhall | Worcester, Mass. |
| A. H. Purdue | Fayetteville, Ark. |
| A. B. Reagan | Mora, Wash. |
| Alfred Springer | Cincinnati, Ohio. |
| Robert B. Warder | Washington, D. C. |
| Ernest Walker | Clemson College, S. C. |
| G. W. Wilson | Fayette, Ia. |

## *ACTIVE MEMBERS.*

| | |
|---|---|
| C. E. Agnew | Delphi. |
| L. E. Allison | West Lafayette. |
| H. W. Anderson | Ladoga. |
| H. F. Bain | San Francisco, Cal. |
| Walter D. Baker | Indianapolis. |
| Edward Hugh Bangs | Indianapolis. |
| W. H. Bates | West Lafayette. |
| Lee. F. Bennett | Valparaiso. |
| Harry Eldridge Bishop | Indianapolis. |
| Lester Black | |
| William N. Blanchard | Greencastle. |
| Charles S. Bond | Richmond. |
| H. C. Brandon | Bloomington. |
| Fred J. Breeze | Remington. |
| E. M. Bruce | Terre Haute. |
| Lewis Clinton Carson | Detroit, Mich. |

[2—21363]

Herman S. Chamberlain . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
E. J. Chansler . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bicknell.
A. G. W. Childs . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Kokomo.
C. D. Christie . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . West Lafayette.
Howard W. Clark . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Chicago, Ill.
Otto O. Clayton . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Geneva.
H. M. Clem . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Monroeville.
Charles Clickener . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Silverwood, R. D. No. 1.
Charles A. Coffey . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Petersburg.
William Clifford Cox . . . . . . . . . . . . . . . . . . . . . . . . . . . Columbus.
J. A. Cragwall . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Crawfordsville.
M. E. Crowell . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Franklin.
Lorenzo E. Daniels . . . . . . . . . . . . . . . . . . . . . . . . . . . . Laporte.
E. H. Davis . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . West Lafayette.
Charles C. Deam . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bluffton.
Martha Doan . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Westfield.
J. P. Dolan . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Syracuse.
Herman B. Dorner . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Urbana, Ill.
Hans Duden . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
Arthur E. Dunn . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Logansport.
Herbert A. Dunn . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Logansport.
M. L. Durbin . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Anderson.
J. B. Dutcher . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bloomington.
A. A. Eberly . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . West Lafayette.
C. R. Eckler . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
Max Mapes Ellis . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Vincennes.
H. E. Enders . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . West Lafayette.
Samuel G. Evans . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Evansville.
William P. Felver . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Logansport.
C. J. Fink . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Crawfordsville.
M. L. Fisher . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . West Lafayette.
A. S. Fraley . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Linden.
Austin Funk . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Jeffersonville.
John D. Gabel . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Madison.
Andrew W. Gamble . . . . . . . . . . . . . . . . . . . . . . . . . . . . Logansport.
H. O. Garman . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Lafayette.
J. B. Garner . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Crawfordsville.
Robert G. Gillum . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Terre Haute.

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|---|---|
| Vernon Gould | Rochester. |
| Frank Cook Greene | New Albany. |
| Walter L. Hahn | Springfield, S. D. |
| C. F. Harding | West Lafayette. |
| Mary T. Harman | State College, Pa. |
| Victor Hendricks | St. Louis, Mo. |
| John P. Hetherington | Logansport. |
| C. E. Hiatt | Bloomington. |
| John E. Higdon | Indianapolis. |
| Frank R. Higgins | Terre Haute. |
| S. Bella Hilands | Madison. |
| John J. Hildebrandt | Logansport. |
| G. E. Hoffman | Logansport. |
| Allen D. Hole | Richmond. |
| Lucius M. Hubbard | South Bend. |
| O. F. Hunzicker | West Lafayette. |
| John N. Hurty | Indianapolis. |
| J. Isenberger | Lebanon. |
| C. F. Jackson | Durham, N. H. |
| A. G. Johnson | Lafayette. |
| H. E. Johnson | Greenfield. |
| A. T. Jones | West Lafayette. |
| W. J. Jones, Jr | West Lafayette. |
| O. L. Kelso | Terre Haute. |
| A. M. Kenyon | West Lafayette. |
| Frank D. Kern | Lafayette. |
| Charles T. Knipp | Urbana, Ill. |
| L. V. Ludy | West Lafayette. |
| R. W. McBride | Indianapolis. |
| Richard C. McClaskey | Terre Haute. |
| N. E. McIndoo | Lyons. |
| Edward G. Mahin | West Lafayette. |
| James E. Manchester | Vincennes. |
| Wilfred H. Manwaring | Bloomington. |
| William Edgar Mason | Borden. |
| Clark Mick | Berkley, Cal. |
| A. R. Middleton | West Lafayette. |
| G. Rudolph Miller | Indianapolis. |

F. A. Miller . . . . . . . . . . . . Indianapolis.
Richard Bishop Moore . . . . . . . . . . . . Indianapolis.
F. W. Muncie . . . . . . . . . . . . Crawfordsville.
Fred Mutchler . . . . . . . . . . . . Terre Haute.
Charles E. Newlin . . . . . . . . . . . . Indianapolis.
John F. Newsom . . . . . . . . . . . . Stanford University, Cal
J. A. Nieuwland . . . . . . . . . . . . Notre Dame.
D. A. Owen . . . . . . . . . . . . Franklin.
Rollo J. Pierce . . . . . . . . . . . . Indianapolis.
Ralph B. Polk . . . . . . . . . . . . Greenwood.
James A. Price . . . . . . . . . . . . Ft. Wayne.
C. A. Reddick . . . . . . . . . . . . Crawfordsville.
C. J. Reilly . . . . . . . . . . . . Syracuse.
Allen J. Reynolds . . . . . . . . . . . . Emporia, Kansas.
Giles E. Ripley . . . . . . . . . . . . Decorah. Iowa.
George L. Roberts . . . . . . . . . . . . Lafayette.
J. Schramm . . . . . . . . . . . . Crawfordsville.
E. A. Schultze . . . . . . . . . . . . Chicago, Ill.
Will Scott . . . . . . . . . . . . Bloomington.
Charles Wm. Shannon . . . . . . . . . . . . Bloomington.
Fred Sillery . . . . . . . . . . . . Indianapolis.
J. R. Slonaker . . . . . . . . . . . . Madison, Wis.
C. Piper Smith . . . . . . . . . . . . Pacific Grove, Cal
Essie Alma Smith . . . . . . . . . . . . Bloomington.
E. R. Smith . . . . . . . . . . . . Indianapolis.
J. M. Stoddard . . . . . . . . . . . . Indianapolis.
J. C. Taylor . . . . . . . . . . . . Logansport.
Albert W. Thompson . . . . . . . . . . . . Owensville.
W. P. Turner . . . . . . . . . . . . West Lafayette.
W. B. Van Gorder . . . . . . . . . . . . Worthington.
H. S. Voorhees . . . . . . . . . . . . Ft. Wayne.
Frank B. Wade . . . . . . . . . . . . Indianapolis.
Daniel T. Weir . . . . . . . . . . . . Indianapolis.
A. E. White . . . . . . . . . . . . Connersville.
Herbert Milton Woollen . . . . . . . . . . . . Indianapolis.
J. F. Woolsey . . . . . . . . . . . . Indianapolis.
G. A. Young . . . . . . . . . . . . West Lafayette.
L. E. Young . . . . . . . . . . . . West Lafayette.

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|---|---|
| W. J. Young | Hyattsville. |
| Lucy Youse | Palo Alto, Cal. |
| W. A. Zehring | West Lafayette. |
| Charles Zeleny | Bloomington. |

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|---|---|
| Fellows, resident | 48 |
| Fellows, non-resident | 10 |
| Members, active | 131 |
| Members, non-resident | 25 |
| Total | 214 |

NOTE.—For list of Foreign Correspondents, see Proceedings of 1904.

# PROGRAM

OF THE

## *TWENTY-FOURTH ANNUAL MEETING*

# INDIANA ACADEMY OF SCIENCE,

## PURDUE UNIVERSITY, LAFAYETTE, INDIANA,

## *NOVEMBER 26, 27 AND 28, 1908.*

OFFICERS AND EX-OFFICIO EXECUTIVE COMMITTEE.

GLENN CULBERTSON, President
A. L. FOLEY, Vice-President
J. H. RANSOM, Secretary
A. J. BIGNEY, Assistant Secretary
G. A. ABBOTT, Press Secretary
W. A. McBETH, Treasurer

| | | |
|---|---|---|
| DAVID M. MOTTIER | D. W. DENNIS | J. C. ARTHUR |
| ROBERT HESSLER | C. H. EIGENMANN | O. P. HAY |
| JOHN S. WRIGHT | C. A. WALDO | T. C. MENDENHALL |
| C. L. MEES | THOMAS GRAY | JOHN C. BRANNER |
| W. S. BLATCHLEY | STANLEY COULTER | J. P. D. JOHN |
| H. W. WILEY | AMOS W. BUTLER | JOHN M. COULTER |
| M. B. THOMAS | W. A. NOYES | DAVID S. JORDAN |

All sessions of the Academy will be held in the Chemical Building on the campus of Purdue University. Rooms will be provided in this building for the Secretary and other officers, and for committees. A general lounging room will also be furnished.

ENTERTAINMENT.

Arrangements have been made to care for those attending the Academy in fraternity houses within two blocks of the University grounds. A very low rate of $1.50 has been secured for supper on Friday night, night's lodging and breakfast on Saturday morning.

On Friday noon a lunch will be served at the University for 50 cents.

Those desiring to have accommodations reserved for them should notify Dean Stanley Coulter at once.

All attending the Academy should report at once at the Chemical building, where their reservation will be given them and they will then be shown to their lodging places.

PROGRAM COMMITTEE.

M. B. Thomas, Crawfordsville
C. H. Eigenmann, Bloomington
Glenn Culbertson, Hanover

LOCAL COMMITTEE.

Stanley Coulter
Percy N. Evans
C. H. Benjaman

## GENERAL PROGRAM.

### THURSDAY, NOVEMBER 26.

Meeting of the Executive Committee at the Lahr House........................................ 8:30 p. m

### FRIDAY, NOVEMBER 27.

CHEMICAL BUILDING.

General Session.............................................................................. 9:00 a. m.
President's Address.......................................................................... 11:00 a. m.
Lunch at the University...................................................................... 12:00 m.
Inspection of University and Exhibits........................................................ 1:00 p. m.
Section Meetings............................................................................. 2:30 p. m.
Lecture and Demonstration—High Frequency Currents. By Professor H. T. Plumb, Associate Professor of Electrical Engineering, Purdue University. Lecture Room, Electrical Building........ 8:00 p. m.

### SATURDAY, NOVEMBER 28.

CHEMICAL BUILDING.

General Session followed by Section Meetings.................................................. 9:00 a. m.
Round Table.

## PAPERS TO BE READ.

At eleven o'clock November 27 the Academy will hear the address of the retiring president, Professor Glenn Culbertson, on "Deforestation and Its Effects Among the Hills of Southern Indiana."

### GENERAL.

1. Work of the Pathological Laboratory of the Central Indiana Hospital for the Insane, 15m.......... Dr. Geo. F. Edenharter
* 2. New Species of Birds in Indiana, 10m.......... Amos Butler
* 3. The Recent International Congress on Tuberculosis, 10m.......... Severance Burrage
* 4. Biography and the Influence of Environment, 15m.......... Robert Hessler
* 5. Felkner Island, Wabee Lake, Kosciusko County, Indiana, 10m.......... J. P. Dolan
6. A Strange Nurse, 5m.......... A. J. Bigney
* 7. The Shake Dance of the Quilente Indians, with drawing, by an Indian in the Indian School. Presented by.......... Albert B. Reagan
* 8. Invasion of School Building by Bed Bugs, Acanthia Hirundinis, Parasites on Chimney Swifts.. H. E. Enders
* 9. Photographs of Morehouse's Comet, 1908 (lantern).......... W. A. Cogshall
*10. Selective Fertilization Among Fishes.......... W. J. Moenkhaus
*11. Nature Study.......... J. G. Coulter

### BOTANY.

* 1. Field Observations on Rusts for the General Botanist, 5m.......... J. C. Arthu
* 2. The Rust of Timothy, 10m.......... F. D. Kern
* 3. Notes on the Heteroecious Rusts of Indiana, 10m.......... Aaron G. Johnson
* 4. Some Anomalies in the Endosperm of Pinus, 5m.......... D. M. Mottier
* 5. Notes on the Seedless Persimmon, 5m.......... Wm. L. Woodburn
* 6. A Preliminary List of the Fungi of Indiana, 5m.......... J. M. VanHook

*Papers read.

* 7. Testing Seed Corn by Specific Gravity, 5m . . . . . . . . . . . . . . . . . . H. A. Dunn
* 8. Notes on the Flora of Cass County, Indiana, 10m . . . . . . . . . . . . . . . Robert Hessler
* 9. Bean Anthracnose, 10m . . . . . . . . . . . . . . . . . . . . . . . . . . . M. F. Barrus
*10. Endophytic Algae, 10m . . . . . . . . . . . . . . . . . . . . . . . . . . . Jacob Schramm
*11. Report of Work in Corn Pollination, 5m . . . . . . . . . . . . . . . . . . . M. L. Fisher
*12. Effect of the Recent Drought Upon Forest Trees, 10m . . . . . . . . . . . . . Stanley Coulter
*13. Difference Between Pinus taeda and Pinus palustris, 10m . . . . . . . . . . . Katherine G. Bitting
14. A Forest Problem, 10m . . . . . . . . . . . . . . . . . . . . . . . . . . . W. H. Freeman
*15. Botany in the High School, 10m . . . . . . . . . . . . . . . . . . . . . . . E. C. Snarr
*16. The Killing of Mustard and Other Noxious Weeds in the Grain Fields of South Dakota, 10m . . . . E. W. Olive
*17. The Plankton of an Underground Stream . . . . . . . . . . . . . . . . . . . Will Scott
18. Anthracnose on Cereals and Grasses . . . . . . . . . . . . . . . . . . . . . A. D. Selby and T. F. Manns

## CHEMISTRY AND MATHEMATICS.

* 1. The Meyer Molecular Weight Calculation, 10m . . . . . . . . . . . . . . . . Percy N. Evans
* 2. The Vapor Pressure Method of Determining Molecular Weights, 15m . . . . . . . J. B. Garner
3. Reaction of Sulphuric Acid Interpreted Upon the Basis of the Electrolytic Dissociation Theory, 10m . . . . . . . . . . . . W. A. Ruth
* 4. Action of Alpha Bromacylesters on Sodium Acetylacetone, 10m . . . . . . . . . G. A. Reddick
* 5. Action of Alpha Bromacylesters on Sodium Benzoylacetone, 10m . . . . . . . . J. B. Garner and G. J. Fink
* 6. Relation of Fats to Moisture Content of Butter, 10m . . . . . . . . . . . . O. F. Hunziker
7. Note on a Class of Definitions, 5m . . . . . . . . . . . . . . . . . . . . . F. R. Higgins
8. A Graphical Representation of the Epsilon-Delta Definition of the Limit of a Function and Continuity, 5m . . . . . . . . . . . . F. R. Higgins
* 9. The Beckmann Rearrangement . . . . . . . . . . . . . . . . . . . . . . . . J. B. Garner
*10. The Use of the Polariscope in Testing High Tension Insulators . . . . . . . . C. F. Harding
*11. A Contribution to the Chemistry of Mucoid . . . . . . . . . . . . . . . . . C. E. May
*12. The Determination of Lead by Titration of Lead Chromate . . . . . . . . . . C. E. Brooks
*13. An Evolution Method for the Determination of Sulfur in Sulfates and Sulfides . . . . F. C. Mathers
*14. The Deterioration of Platinum through Ignition of Phosphates . . . . . . . . R. E. Lyons

## GEOLOGY.

* 1. Probable Origin of Depressions in the Mesa South of the Tijeras Canyon, New Mexico, 10m . Albert B. Reagan
* 2. Headwaters of the Tippecanoe River, 10m . . . . . . . . . . . . . . . . . . J. T. Scovell
* 3. Origin of Cyclones and Anticyclones of Temperate Latitudes, 10m . . . . . . W. A. McBeth
4. Some Drainage Modifications in Southeastern Indiana . . . . . . . . . . . . W. M. Tucker
5. Soil Survey of Daviess County . . . . . . . . . . . . . . . . . . . . . . . L. C. Snyder
6. Caves and Cave Formations of the Mitchell Limestone of Indiana . . . . . . . F. C. Greene

## ZOOLOGY.

1. The Nasal Muscles of the Reptiles, 10m . . . . . . . . . . . . . . . . . . H. L. Bruner
2. Swell Mechanisms of Vertebrates, 10m . . . . . . . . . . . . . . . . . . . H. L. Bruner
* 3. Life Zones of Indiana as Illustrated by the Distribution of Orthoptera and Coleoptera Within the State, 15m . . . . . . . . . . . . W. S. Blatchley
* 4. Animals of the Olympic Peninsula, Washington, 10m . . . . . . . . . . . . . Albert B. Reagan
5. The Effect of Successive Removal on the Rate of Regeneration . . . . . . . . Charles Zeleny
6. Proportional Regeneration . . . . . . . . . . . . . . . . . . . . . . . . . M. M. Ellis
7. Curves Representing the Rate of Regeneration . . . . . . . . . . . . . . . . M. L. Durbin
8. Circulation of Mixed Blood in the Adult Reptile and Amphibian as well as in the Fetal Mammal and Bird . . . . . . . . . . . . A. G. Pohlman

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*Papers read.

## EXHIBITS AND DEMONSTRATIONS.

All of the laboratories of the University will be open for inspection during the session of the Academy and from 1:00-2:30 on Friday members of the Instruction Staff will be present to explain apparatus and methods of work.

Some special exhibits will be made as follows:

### TESTING LABORATORY OF THE MECHANICAL BUILDING.

In the Timber Testing Laboratory will be demonstrated the methods used in the Forest Service for testing wood.

### CHEMICAL BUILDING.

Exhibit of Literature and Apparatus used in the fight against Tuberculosis.

### AGRICULTURAL BUILDING.

The Departments of Agronomy and Extension Work and the State Chemist will make exhibits in the Soil Physics Laboratory and the Agronomy Class Room.

The Department of Agricultural Engineering will exhibit in Room 201.

The Department of Animal Husbandry will exhibit micro-photographic work, hog cholera vaccine and other research work in the Veterinery Science Laboratory and Museum.

### HORTICULTURAL LABORATORY.

Exhibit of appliances used in spraying infected plants.

### DAIRY LABORATORY.

Exhibit of appliances used in the care of dairy products.

### UNIVERSITY FARM.

Exhibit of experimental feeding work, the dairy herd and various breeds of sheep and hogs.

# The Twenty-Fourth Annual Meeting of the Indiana Academy of Science.

The twenty-fourth annual meeting of the Indiana Academy of Science was held at Purdue University, Lafayette, Indiana, Thursday, Friday and Saturday, November 26, 27 and 28, 1908.

Thursday evening the Executive Committee met at the Lincoln Club and transacted the business coming before them. They directed the Secretary to request of the Legislative Committee, having the matter in charge, the doubling of the appropriation for the Academy. It was voted that the next meeting be a celebration of the twenty-fifth anniversary of the founding of the Academy and that an attempt be made to bring together all the educational interests of the State, as well as to have present all the living ex-Presidents of the Academy.

At nine o'clock Friday morning the Academy met in the chemistry building at Purdue. President Culbertson presided. The transaction of business and the reading of papers occupied the attention of the meeting until eleven o'clock, when the President delivered his address on "Deforestation and Its Effects Among the Hills of Indiana."

At noon a luncheon was served on the top floor of the chemistry building, followed by an inspection tour of the buildings of the University.

On reconvening at two o'clock a short business meeting was held, after which papers were read in sectional meetings. In the evening Professor H. T. Plumb, of the University, delivered an interesting lecture on the subject of "High Frequency Electric Currents."

Saturday morning at nine o'clock the Academy reconvened and completed the reading of papers and the transaction of business, adjourning at eleven o'clock to meet in next annual session at time and place selected by the program committee.

# President's Address:

## Deforestation and Its Effects Among the Hills of Southern Indiana.

By Glenn Culbertson.

No region of America, east of the Rocky Mountains, was in the past more densely wooded than were the hills and valleys of southern Indiana. Some of the most magnificent specimens of the temperate latitude forest trees found a suitable habitat along the crests of the divides, and upon the valley slopes of the Ohio River and its tributaries. Very few unwooded areas were found among the hills of southern Indiana, and such as were present were not large.

The "flats" or "slash" lands, forming the watersheds between the Ohio and the Wabash and their tributaries in many parts of southeastern Indiana, were occupied largely by the sweet gum, or liquidamber, the black gum, beech, shell-bark hickory, black-jack and red oaks, red maple and hackberry.

On the gently-rolling land and among the hills the yellow poplar, white and chinquapin oaks, the black walnut, sugar maple, beech, hickory, buckeye, black locust, linn or basswood, the white and blue ash, and on the still more precipitous and rocky ridges the chestnut oak and cedar, were found.

In the rich alluvial bottoms, and along the streams, in addition to many of the rolling land trees, were present in their greatest luxuriance the elm, the cottonwood and the sycamore. Many of these trees were among the giants in dimensions. There were yellow poplars from one hundred to one hundred and twenty-five feet in height, and from twenty to twenty-five or more feet in circumference. Sycamores grew along the larger streams and in the river bottoms, of such dimensions that their hollow trunks were sometimes used as rude dwellings and as stables.

White oaks and black walnuts grew to such size and in such profusion that were they to be had now, in their original numbers, their value would be twenty-fold greater than the present value of the land from which they were cut.

To clear the ground of such a forest growth, the pioneers had indeed a difficult task. After a generation of fierce fighting on the part of our fathers that they might overcome their then common enemy, the forest, it is not at all surprising that it is even yet difficult to bring the present generation to a proper realization of the benefits of the living forest. All appreciate the value of the timber, but very few of the people realize the benefits of the forest to the country at large; nor do they yet understand the methods by which forest lands may be made as profitable as cultivated areas. To cut away the trees, and to bring the land under cultivation, appears to be the great purpose of the majority of those still possessing a few acres of woodland. To such an extent has the work of deforestation been carried on, even among the hills of southern and southeastern Indiana, that less than ten per cent of the original forest areas are still left intact. Those portions of the original forests yet standing have in the greater number of instances not more than 30 per cent of their former number of trees.

Contrary to what might have been supposed, a larger per cent of the steep hill slopes has been cleared than the land of the more level regions. The slopes of the higher hill lands, such as are found in portions of Clark, Jefferson, Switzerland, Ohio, and Dearborn counties, and to an equal extent in the river counties to the southwest and in the adjoining State of Kentucky, have been almost entirely denuded of their forest growth. Here and there, however, on land that has become valueless for agricultural purposes, nature has begun to repair the general destruction, and a scattering growth of bushes and young trees has sprung up.

It is the purpose of this paper to treat of some of the questions, geological and meteorological, as well as economic, arising from the deforested conditions found in the hills of southern Indiana. Special study, however, has been made of the regions comprised in the basins of Fourteen Mile, Indian Kentucky, Indian and Laughery creeks and the smaller streams emptying into the Ohio River in Clark, Jefferson, Switzerland, Ohio, Dearborn and Ripley counties. What may be said of this general region is largely applicable likewise to other localities with approximately similar conditions.

One of the most striking effects of the deforestation of this region has been upon the "immediate run off" of the streams. As could have been predicted, the amount of this "immediate run off," for any given precipitation, has rapidly increased as the forests have disappeared. The volume

of the flood waters of the streams has year by year kept pace with the destruction of the wooded areas. This has been notably true of the volume of the different tributaries of Indian Kentucky Creek, which has come more immediately under my observation. Within the last ten years these streams have repeatedly had record-making floods.

It has been estimated that, upon all the lands of the earth, some 36,000 cubic miles of water fall per year, and that of this amount some 6,000 cubic miles finds its way into the sea by way of the rivers and streams. Thus the annual average run off from the lands is approximately 16 per cent. The average "immediate run off" of such streams as obtain their water supply from the hills referred to in this paper must have varied enormously with the change from the completely forested condition of the past to that of the present. Then, there was a universal leaf mulch, and a deep, porous soil, filled with roots and decaying vegetation. As compared to that, there is now a compact sod, a shallow and very compact clay or a rock surface. The average annual "immediate run off" from these streams today is at least 50 per cent greater than that from the same regions under the forested conditions of the past.

One of the most apparent consequences of the greatly increased "immediate run off" is the gradual lowering of the ground water level in all portions of the State and especially among the hills. As the ground water level is lowered the flow of springs and of wells is stopped, or very much reduced, in time of drouth. At no time in the history of southern Indiana and northern Kentucky have springs and wells so completely failed as has occurred during the season just past. Water for family use and for stock has in hundreds of instances, and during many weeks, been obtained from distances of one or two miles. The water supply in villages and small towns became very limited or gave out entirely. In many parts of the State, even at a distance from those portions having a rough topography, wells are being driven to greater and greater depths in the endeavor to obtain a permanent water supply for mills and factories, as well as for farm animals. These unfortunate conditions may properly be attributed in large part to the greater immediate run off of the rainfall resulting from deforested conditions.

That deforestation in general, and in the regions referred to in this paper in particular, causes a decrease in the total precipitation can hardly be doubted. The problem of the influence of forests on precipitation is one not easily solved, and is one which has long troubled investigators.

It appears to the writer that both theory, and the observation of the phenomena, substantiates the statement that deforestation greatly influences the rainfall.

It is not probable that the ordinary winter and spring precipitation is to any extent affected by the presence or absence of forest growth. That the summer and autumn rains are often greatly modified, on the other hand, can hardly be questioned.

In the first place, the presence of a heavy leaf mulch, and of the very porous and highly-absorbent soil of a forested area, is a sufficient guarantee that at the beginning of the hot season the soil shall be filled with moisture from the winter and spring rains. Under the present deforested conditions of the hill lands the immediate run off is so great, because of their compact and rocky surfaces, that it is at least questionable whether the ground is ever fully saturated, even at the beginning of the summer season. Moreover, if such a compact soil were saturated, capillary action would cause a very rapid evaporation during the first few weeks of warm weather, and hence greatly diminish the supply of ground water before midsummer.

Given, however, the soil and subsoil of a forested region thoroughly saturated with water at the opening of the hot season, the leaf and loose soil mulch effectively stops evaporation resulting from capillary action. The ground water then is largely conserved until drawn from the soil by means of the roots of the forest trees, and evaporated from the leaf surfaces later in the season, when the trees need the moisture for growth. It is a well-known fact that the evaporation from the leaf surfaces of the greater number of trees in a moist climate is very important. Carefully conducted experiments have shown that from the leaves of a birch tree of moderate size, from 600 to 900 pounds of moisture is evaporated in twenty-four hours, and that from a large elm there may be given to the atmosphere as much as several tons in the same period. The amount, however, varies very considerably with the atmospheric conditions. It is a fact of common observation that large trees, such as the oak, growing in cultivated fields, so completely take up the moisture from the earth that the corn or other crop fails to mature for a distance of many yards from them.

In a forested region the approach of a low barometric area, with its accompanying high temperature conditions, in accordance with the laws of vaporization, causes a corresponding increase of evaporation from the

foliage. Moreover, as the evaporation increases, in the same degree the temperature is modified, since the greater the amount of water changed into vapor the greater the quantity of heat absorbed in the process. Reducing the temperature increases the relative humidity of the atmosphere. Hence, in two ways the atmospheric conditions are made more favorable for a copious and general rainfall at the approach of low barometric areas during the hot season.

It has always been true, perhaps, that many thunder-storms and showers during the summer months, and particularly in July and August, give moisture to very limited areas. Careful observation during a number of years has convinced the writer that as the forests have disappeared the average territory covered by our summer thunder-storms has been gradually and greatly decreasing. Repeatedly during the last few hot seasons, and especially during the one just past, the arrival of a low barometric area caused the formation of a few thunder-clouds, but these, instead of increasing in volume and advancing so as to cover a larger and larger region, soon dwindled and disappeared. The failure of the present deforested areas to add to the sum total of the general atmospheric moisture, as the heated conditions of the low barometric area approached, and also the failure in the formation of vapor in the given locality, both served to decrease the rainfall of the thunder-storm. This was due, first, to the lack of a local vapor supply to add to that brought in by the winds from a distance, and which is very necessary for the formation of clouds in the hot season. Again, when the supply of moisture may have been sufficient to form a thunder-cloud, its advance was into a highly heated dry region with its low relative humidity. The absence of any considerable local evaporation, and the resulting high temperature caused the re-evaporation of the condensed moisture of the clouds and no precipitation followed.

The weather conditions of the deforested areas during the hot months are more and more nearly approaching those of the hot arid regions of the west, where a thunder-cloud formed under favorable conditions very frequently disappears because of re-evaporation as it advances into a territory more highly heated, and of a lower relative humidity.

In another way also the presence of forests tends to add to, and their absence to diminish, the precipitation of the summer months, and that is in causing secondary showers after the main storm is over. The enormous leaf surface, covered with moisture by the rain just passed.

causes a very rapid evaporation to take place almost immediately. Hence, during the hot months, a number of secondary showers quite often followed a thunder-storm under forested conditions. The old weather adage that "Fog rising from the hills will soon give water to the mills," seldom failed of fulfillment. The benefits derived from the more gently falling showers following the hard downpour of the thunder-storm in filling the soil of the cultivated fields and pasture lands can hardly be estimated. It is the moisture from these rains that adds very greatly to the ground water, especially on the firmer earth surfaces.

Again, if it be true, as now appears from records kept during the last ten years, that the summer rainfall of the trans-Mississippi states, particularly Oklahoma, Kansas and Nebraska, be increasing, it would uphold the theory just advanced. In contrast with the naked prairie of the past, which had a large immediate run off, the plowed lands of today are a much better absorber of moisture, and would increase very much the ground water supply. The early summer cultivation of extensive cornfields would tend to conserve this moisture, until the rank growth of corn or other cultivated vegetation, with its extensive leaf surface, would add greatly to the evaporating surface. This would increase the local atmospheric moisture, especially during July and August. Hence, if the above theory be true, there should be ordinarily an ever-increasing rainfall during those months year by year, just in proportion to the area of original prairie land put under cultivation. If trees were more extensively planted, the results in increased rainfall should be marked to the same degree.

In résumé, we may say that theory upholds, and observation substantiates the statement, that deforestation greatly increases the immediate run off, and as greatly decreases the ground-water supply of a given region. It is equally true that the absence of forests seriously decreases the evaporation, and the amount of vapor in the atmosphere, during the hot months. Again, the absence of evaporation permits of higher local temperatures on the approach of low barometric areas and hence the relative humidity of the atmosphere must be lower. All tend toward the reduction of the rainfall during the late summer months, when of all times it is most needed for the growth and maturing of vegetation.

Furthermore, we believe that it can be shown that deforestation has a tendency in a region of rough topography, such as is found among the hills of southern Indiana, to localize the hot season rainfall, and to produce conditions approximating those of the so-called "cloudbursts" of the

Rocky Mountain regions of the West. A case in point occurred during the past summer in the latter part of July over an area of some six or eight square miles along the divide between the basins of Indian Kentucky and Indian creeks and their tributaries, in eastern Jefferson and western Switzerland counties of this State. The rainfall in this case was unprecedented for the region. On one border of the given area a government rain gauge, kept by J. R. Shaw, Jr., was filled to the brim, the measurement amounting to three and one-half inches, and then ran over for an unknown period. Afterward the gauge was emptied and received one and one-half inches more, making at the least five inches, and probably much more, in the period of two hours during which the rain fell. Other and more reliable measurements in locations more nearly the center of the storm area were made and a precipitation of at least ten inches in the two-hour period were recorded.

The conditions producing this exceptional and very destructive rainstorm were as follows: The region to the west and southwest of the storm-swept region is one of the roughest topographically in southern Indiana. The whole area for ten or twelve miles in this direction forms the basin of Indian Kentucky Creek and tributaries, and the hills rise in many instances 400 to 450 feet above the valleys, and the slopes are very steep. From the whole basin the forests have been almost entirely removed. On the day referred to the temperature was unusually high, some thermometers within the area registering 102 degrees in the shade. There was no movement of the air until early in the afternoon, when a gentle southwest wind arose, and this caused the highly-heated air of the whole region to move northeastward. The valley of Brushy-fork Creek, one of the principal tributaries of Indian Kentucky Creek, became the center of the air movement. About three in the afternoon a cloud began to form above the divide and around the head of the valley of Brushy-fork Creek. The highly-heated air ascended very rapidly on reaching the divide, and the consequent rapid cooling of the air by expansion caused an equally rapid condensation of the moisture of the air. The cloud increased in volume with very great swiftness, and the rain fell in torrents, first over a very limited area and then over a wider region. The center of the storm, however, instead of moving, as is usually the case, remained almost stationary for a period of two hours. During this time the winds from almost the entire surrounding region moved slowly towards the now enlarged area of precipitation. There were few if any clouds outside of

the six or eight square miles covered by the storm, but the hot air from the proximity, on reaching this area of rapidly rising atmosphere, constantly added its moisture to that being condensed, with the result that for two hours the downpour continued. This very unusual precipitation proved exceedingly disastrous to the soil of the cultivated fields, and to the roads and bridges as well as to property of all kinds along Brushyfork Creek and the larger tributaries of Indian Creek. Both of these streams were several feet above any previous record. Where a few moments before there were dry, rocky creek beds, now became a wild flood from six to ten feet in depth and from 300 to 500 feet wide. Buildings were carried away that had seldom or never been touched by previous floods.

In the opinion of the writer this cloudburst, which in truth it was, was caused by the intense heating of the deforested region of very rough topography to the southwest, followed by the gentle movement of great volumes of heated air in a northeasterly direction, until in its passage over the divide it rapidly ascended. Becoming cooled in its ascent, the enormous quantity of moisture held in the highly-heated atmosphere rapidly condensed, and the unprecedented rainfall for that region followed. It may be years before conditions of temperature, moisture and winds would unite to produce another such storm in the same locality, yet the probabilities are that in the future such rainfalls will become increasingly frequent somewhere in such deforested areas of rough topography.

From observations in the Rocky Mountains of Colorado and Wyoming, the cloudbursts of those regions are formed under essentially similar conditions, so far as the absence of forests and areas of highly-heated air are concerned. In the mountains, however, these storms may be more intense, and more frequent, because of the greater height of the divides and the almost entire absence of vegetation or even of any considerable mantle of soil.

Observation of the hill region of southern Indiana compels one to believe that as the forest growth has disappeared such storms have become more prevalent. Excessive rainfall occurs over limited areas, while drouth conditions prevail over the surrounding country. In the one place of rainfall the destruction caused by the flood may be even more disastrous than the continued drouth over the nearby territory.

The effect of forest destruction upon streams has often been described and need not be dwelt upon in this paper at any length. In the area

of hill lands of southern Indiana there can be no reasonable doubt that as the trees have been removed there have been greater and greater floods; and now as the forests have almost entirely disappeared the floods have become exceedingly destructive. Dwelling houses that had stood above the highest waters of the streams for half a century have, within the last decade, since the higher prices for timber have caused the more rapid disappearance of the trees, been inundated repeatedly and many of them carried away. Bottom lands that twenty years ago had a deep and fertile soil are now almost worthless. The flood waters have carried away the greater part of the tillable earth and left in its place stones and gravel. In other places the alluvium of the bottoms has been covered by material from the hills. Thousands of acres of such land, which a few years ago was the most fertile and valuable in the State, are now undesirable.

Hand in hand with the flooded conditions and consequent destruction caused by the larger streams has gone the loss of soil by erosion from the deforested hill lands. It is no exaggeration to say that, from the greater number of hill farms placed under cultivation a quarter of a century ago, there has been removed on the average a foot of soil, and from many slopes there has been taken three or four times as much. Tens of thousands of acres of the steeper hillsides have been denuded of their soil covering and are at present valueless for ordinary agricultural purposes. How to prevent this denudation is the most serious problem that the hill farmer has to solve. In many cases a single heavy rain in February or March, when the departing frost has left the ground in its least compact condition, has been known to remove from a whole slope an average of four or five inches of the soil. Fields that before the rain were considered good farming land were left so covered with rocks, and with so little soil, that they were practically abandoned. Farmers among the hill lands are realizing more and more that a loss of soil is the most serious of property losses, since a damage of this character cannot be repaired except by the ordinary processes of nature, which require scores and even hundreds of years. Farm after farm in southern Indiana, considered very valuable thirty years ago, is practically deserted today. The population of this region first occupied the hills, and considered the soils of the flats and divides very undesirable. For many years now, however, the tide of movement of the people has been from the hills to the flat or gently rolling

lands. As a result the population and wealth of many of the hill counties have been gradually and greatly diminishing.

Many of the streams, flowing down steep beds in their short courses from the divides to the Ohio, at one time furnished valuable water power. They are now useless. Were it possible to control such streams as Fourteen Mile, Indian Kentucky, Indian and Laughery creeks and many others in Clark, Jefferson, Switzerland, Ohio, Dearborn, Ripley and other counties in southern Indiana, very valuable water power could be obtained. Under the present condition of floods and drouths, however, they are valueless as a source of power. Streams that thirty years ago furnished abundant power for mills during ten months of the twelve now are even without flowing water for almost half the time.

The alternate floods and drouths have had a serious effect also upon the animal life of these streams. The great volume of muddy and rapidly-flowing water sweeps thousands of the smaller fish from their proper habitats into larger pools, where they become a prey to their own kind. On the other hand, drying up of the pools of almost every small and of very many of the larger streams causes the destruction of the young of our most valuable game and food fishes as well as of minnows and of crayfish upon which the more highly-prized fishes feed. In the flooded streams following the unusual freshets of March and April of the present year bass and other species of fish ascended the smaller streams almost to their very sources for the purpose of spawning. The severe drouth of the late summer and autumn months dried up the pools and caused the death of such quantities of the young fish and other animal life that the odor of their decaying bodies was very offensive to persons dwelling along the streams near the pools. It would be quite within the truth to say that several wagon loads of minnows and the young of our food fishes thus perished this season in the tributaries of Big and Indian Kentucky creeks in Jefferson County alone. Some of the young bass were removed to larger pools, but thousands upon thousands were destroyed. It would seem almost useless to restock our streams with bass and other valuable food and game fishes if the periodic floods and drouths are to continue and to grow in magnitude and severity.

The points already discussed represent but a part of the evils resulting from deforestation among the hills and valleys of our southern counties. We need not speak of the more manifest economic phases of the subject, such as the failure of the timber and the fuel supply, and the

higher prices resulting. Enough has been said to convince all that the only hope for the future prosperity of great areas of our State lies in reforesting. In the first place, reforestation should be urged upon the present land owners. Many an acre of untillable soil could be planted in black locust, catalpa, black walnut or shell-bark hickory with good prospect of speedy returns upon the investment. Wealthy men, interested in the preservation of game or fish, should be encouraged by favorable laws, or otherwise, to purchase large tracts of the hill lands of the State, and to plant them in timber.

Our State has already made a good, although very small, beginning in forestry. In the writer's opinion it would be the highest economy for the commonwealth to purchase and reforest tens of thousands of acres of her rougher hill lands along the Ohio and other streams. These lands are almost valueless for agricultural purposes. Covered with a growth of our most useful trees, they would in time return a rich revenue to the State; they would again become covered with soil; the present unsightly and unprofitable gullied fields and yellow clay points would disappear; the loose soil and leaf mulch resulting would again absorb great quantities of moisture, reduce the immediate run off, and hence diminish the volume of the flooded streams. At the same time the ground water supply would be greatly augmented; our late summer rains would be more numerous and more copious; wells and springs would be more permanent and give larger volumes, and our most severe drouths, destructive to all life, prevented.

The probabilities are, however, that private enterprise alone will never restore the forests to our hills as fully as the best interests of the people demand, hence the State and Nation must be called upon to take a leading part in reforestation.

# Work of the Pathological Laboratory of the Central Indiana Hospital for Insane, Indianapolis.

By Dr. Geo. F. Edenharter, Superintendent.

The time allotted to review the work of our Pathological Department barely permits even a brief presentation of its policies, methods and results.

It should not be inferred from the name that the work therein is purely of a pathological character, because in addition thereto all methods of clinical investigation—psychical, physiological, chemical, bacteriological, etc.—are employed.

This department had its inception in a desire to establish the work of this hospital upon a scientific basis—to provide our medical staff with facilities for the accurate determination of the character of the diseases met with in institutional life.

It was also our ambition to create a scientific department—a medical center—for the use of the physicians and medical students of the State, wherein the diseases of the mind and nervous system could be clinically studied and, if possible, to determine their cause and formulate methods for their prevention and cure.

We recognized that ultimate success in preventing and controlling these diseases could only be achieved by providing every community with practitioners who had been thoroughly taught the most approved methods of care and treatment of the incipient stages in these cases, and this in connection with a close clinical study of the various forms of insanity.

We knew that the greatest opportunity for successful results presented itself in the early stages of these maladies and therefore determined to exert our energies in an endeavor to provide facilities for the education of the individual who expected at some future time to assume the role of a family physician.

Students who interest themselves in this specialty are urged to visit this department, where every effort will be made to assist them in obtaining a knowledge of the laboratory and clinical methods in vogue.

When requested, our pathologist properly directs their efforts in research in any desired direction.

Our expectations for this department are gradually being realized, and it is with a feeling of personal pride that I am able to make the statement that this hospital is today presenting to the students of the medical colleges of Indiana a course of lectures—didactic and clinical—concerning the diseases of the mind and nervous system, their cause, pathology and treatment, unsurpassed by any educational institution in this country.

We believe that you who are at all conversant with the facts, recognize the many serious obstacles to be overcome in inaugurating and prosecuting work of a scientific character in public institutions.

In the very nature of things there must be many plans, and many defeats, and in the end, when the decisive battle is waged, you may achieve one victory.

It is the hope that this may be the final outcome of our effort wherein we find the sustaining strength to carry the burden.

It is fortunate indeed that we cannot peer into the future and expose to view all the keen anxieties and bitter disappointments which are to be our portion in connection with prospective work.

The building was erected in 1895, and the equipment was installed in 1896.

The dedicatory exercises were held under the auspices of the Marion County Medical Society on December 18, 1896. At this meeting a paper on "The Evolution of the Physiology and Pathology of the Brain and Spinal Cord" was read by Prof. Ludwig Hektoen, M. D., of the Rush Medical College.

Prior to the appointment of a resident pathologist the hospital staff utilized the facilities of this department in making such examinations as occasions demanded. They also performed autopsies.

The first attempt to systematize and direct the work was outlined in the following notice:

"The laboratory work for the staff of the hospital will begin April 1, 1898.

"The department is now ready for making examinations of material for diagnostic purposes.

"Each member of the staff should possess a copy of Stirling's Histology, several dozen glass slides and covers.

"The study will be from ten to twelve in the forenoon, each member to be in the laboratory every other day.

"Attendance upon this course is obligatory.

"When autopsies are made, the assistant physician who had charge of the patient shall assist the pathologist in making it."

Under the above arrangement the hospital staff was given a thorough review of histology, bacteriology, microscopy, chemistry and pathology.

The sphere of work was gradually broadened.

I quote from the report of 1900-1901:

"Two objects have been constantly in mind in developing the work of the laboratory during the past year:

"First. That of enabling the members of the resident medical staff to conduct their study and treatment of the cases committed to the care of the hospital with a knowledge of the pathological basis of disease and a more intimate knowledge of the structure and functions of the nervous system as revealed by recent scientific researches in this field.

"Second. That of placing upon a thorough systematic and working basis the study of the nervous system and organs of those cases upon which an autopsy is allowed.

"In carrying out the former the following methods have been adopted:

"Each morning for two hours, from ten to twelve, three members of the medical staff are engaged in the study of the normal and diseased organs. In these morning classes the work is individual and inductive. In studying an organ, stained, injected and digested sections are first drawn with different magnifications and then descriptions of the same written without the aid of books or teaching. The gross anatomy and anatomical relations of the organs are then reviewed. When this has been accomplished, a pathological section of the same organ is given without the student knowing its designation. From this drawings and written descriptions are made of those parts differing from the normal sections before studied. This having been done, the pathologist goes over the section with him, correcting the work where necessary and pointing out those parts of more importance, and together they arrive at a diagnosis of the diseased condition. From the changes found, the student then constructs the gross appearance of the organ thus diseased and describes the clinical symptoms which would be most likely present during life in a patient so afflicted. The process of reasoning in this work, it will be seen, is practically the same as that which the physician pursues in diagnosing his case upon the wards; here, however, he starts with the diseased organ and builds up his clinical symptoms; there he arrives at the changes in his organ from the clinical evidence. Incorporated with this

work there is constantly a review of the anatomical and physiological relations of the organ studied.

"Besides these morning classes, two evening courses of lectures have been given, the first on 'Clinical Anatomy,' the second on 'The Finer Anatomy of the Nervous System.' In the former, which extended over a period of two months, the time was spent in the study of the normal relations and position of the abdominal and thoracic organs, the staff outlining these by clinical methods on living subjects after the position of each had been indicated by drawings and upon a skeleton.

"To the second series of lectures the physicians of the city were also invited. This course extended over a period of three months.

"The excellent library of the laboratory has been rearranged and two different catalogues made, to enable the staff to carry on their studies with more freedom and to open for them every opportunity to do original work. The medical journals have also been rearranged in regular series, with the same object in view.

"To aid in teaching and study, the gross specimens in the museum have been carefully mounted and arranged in groups. As this is added to from time to time it will form a very important feature in the advantages which the laboratory offers for study.

"Enlarged drawings have been made of Miss Florence Sabin's excellent model of the medulla, pons and mid-brain, to aid in the teaching of this important and very intricate portion of the central nervous system. Nothing could be of more service in enabling the student to grasp the structure of this region than the model which Miss Sabin has constructed."

In 1900 the medical colleges commenced their didactic and clinical lectures to their students. This course, with a variation of the program, has been continued each year. Indiana University also presents an annual course in psychology. The pathologist each lecture-day presents some pathological demonstration, the program for each session being:

Didactic lecture, one hour.
Clinical lecture, one hour.
Pathological lecture, one hour.

Members of the hospital staff alternate in arranging cases for the clinical lectures. This course is free to practioners and students of medicine; others are admitted upon special permission of the superintendent or lecturer.

From the report of 1905 we take the following:

"Beginning October 1, 1903, and continuing until the last of December of the same year a series of lectures and demonstrations was given to the assistant physicians on the anatomical relations and the physiological functions of the various parts of the nervous system, on the different changes produced by the different pathological conditions that were liable to involve them, and upon the clinical symptoms manifested by such involvement.

"After the 1st of January, 1904, regular staff meetings were instituted and held three times weekly, namely, Monday, Wednesday and Friday mornings from 10:30 to 12. At these meetings the assistant physicians alternated in presenting one or more cases. A systematic examination was made of the mental condition and also of the physical condition, where this had not been done beforehand, by the physician in charge, followed by a discussion of the case by those in attendance. A synopsis of the more important clinical features of each case, together with a summary of the clinical manifestations, was recorded.

"The object of these meetings was to create a nucleus upon which more complete clinical records could be built, and for this purpose a short report was made and filed away of each case, pointing out the prominent and characteristic feature of the individual cases presented. An endeavor was also made to determine the underlying conditions that were the probable factors in bringing about the mental disturbance. This problem was found to be an extremely difficult one. Many important factors came into consideration when an attempt was made to bring about a solution of this problem which were most difficult to regulate and control, in many cases wholly impossible, and tended to make this part of the work a source of discouragement and in many respects very unsatisfactory. One of the first essentials in the study of all pathological conditions, whether mental or physical, is, of course, to have a correct conception of the normal, or what is regarded as normal, in the individaul case. Without this one cannot arrive at a definite conclusion as regards the degree and extent of the abnormal conditions that developed or that may do so. In the majority of cases presented very little information was obtainable, apart from that of the commitment record, or from the patients themselves. The former reports, unfortunately, were very incomplete, and the latter almost invariably were more or less distorted or modified by the trend and coloring of the mental disturbance existing. Consequently, any conclusions arrived at

can only be of corresponding value. In addition to this, it is of the greatest importance to have a full report of the heredity, early education, training and environment of each case in order to understand and appreciate the character and nature of the disturbances that may be manifested. And, finally, there is requisite a full report of the results of a complete examination of the patient's condition at the time of admission, or as soon thereafter as possible, both mental and physical, together with a record of the case while in the institution. Without these data it is impossible to place the pathological work in its proper relationship to the clinical aspect, or to place the latter upon a definite pathological basis."

Since the above was written the work has been carried on practically along the same lines, with a constant endeavor to improve the methods and perfect the details.

This year we have undertaken the re-examination of every patient in the hospital in accordance with an approved schedule with regard to the mental and physical condition.

This procedure will be followed in all new cases admitted.

When this work is completed we will have a systematized record of each patient that will be of the greatest practical value.

The Marion County Medical Society has held a number of meetings in this department. These occasions were largely attended and marked by an awakening of professional spirit that was extremely gratifying. It has been the policy of the hospital to have each of these meetings addressed by an eminent medical man.

The first was addressed by Prof. L. Hektoen, of Chicago, upon "The Contributions of Anatomy and Pathology to the Nervous System."

The second by Jos. G. Rogers, M. D., of Logansport, upon "The First Aid to the Insane."

The third by C. B. Burr, M. D., of Flint, Mich., upon "The Care of the Recent Case."

The fourth by Lewellyn F. Barker, M. D., of Chicago, on "The Importance of Pathological and Bacteriological Laboratories in Connection with Hospitals for the Insane."

The fifth by Stewart Paton, M. D., of Baltimore, upon "The Recent Advances in Psychiatry and Their Relation to Internal Medicine."

The sixth was for the purpose of dedicating the new hospital. The attendance at this meeting was the largest of any, there being present upward of three hundred prominent persons.

The seventh, by F. W. Langdon, M. D., of Cincinnati, upon the "Cardio-Vascular and Blood States as Factors in Nervous and Mental Diseases."

A summary of the work done in this department shows:

1. That the laboratory facilities were in daily use for the examination of various tissues, specimens of blood, urine, sputum, etc.
2. That two-hundred and seventy-four autopsies were held and the findings demonstrated and recorded.

   (Under the hospital rule no autopsies are held, except in coroner's cases, without the permission of the relatives.)
3. That many sections of tissues and organs were preserved for chemical, bacteriological and microscopical examination.
4. That one hundred and thirty-six gross specimens were placed in the museum.
5. That twenty papers covering important cases were written.
6. That over four hundred staff meetings were held, at which over five hundred cases were presented for clinical examination.
7. That two hundred and four lectures were given by the colleges to their classes.
8. That one hundred lectures upon neuropathology were delivered to these classes by the pathologist.
9. That thirteen hundred and forty-one cases were taken before the college classes for clinical demonstration.

This record alone, if there were no other advantages to be derived, would fully justify the maintenance of this department.

But there are other reasons for its continuance:

First. Because it stimulates the individual members of the staff to greater professional effort.

Second. It creates a demand for accurate case and clinical histories. This requires more attention to the individual patient.

Third. It incites to study and systematic investigation by having at hand the requisite appliances, books, models, charts, etc.

Fourth. It enables the institution to offer something to the ambitious student seeking an opportunity for medical advancement.

Fifth. It provides instruction to the physicians and the students in the State; prepares them to render early skilled attention to the mentally afflicted in their community. This directly benefits the citizen.

Sixth. It increases the ability of the outside physician to deliver an

intelligent judgment in insanity inquests and dictate a description of the case of value to the hospital.

Seventh. It economizes for the counties and State ultimately by decreasing the number of persons annually committed to this or institutions of like character.

Eighth. It actuates some students to undertake a special study of mental and nervous diseases. With additional opportunities given these, for clinical observation and for practical work in the laboratory, will eventually develop material from which to select physicians for positions in the hospital.

Ninth. It establishes a valuable medium to create harmonious relations between the outside members of the profession and the institution.

Tenth. It affords the hospital staff the benefits of consultations with specialists in all lines of practice.

Eleventh. It collects pathological data for the records and specimens for the museum which will be of incalculable value for future reference and study.

Twelfth. It assists in educating the public to the needs of the hospital and arouses an interest in its behalf.

Thirteenth. It furnishes the medical colleges with clinical advantages unobtainable without the aid of an institution of this character.

Fourteenth. It extends its influence in time to the individual of every community; it teaches that "prevention is better than cure," and that, if the people really desire to impede the "onward march to the hospitals for the insane" in future generations, they must begin at once to heed the advice given, assist in locating and studying the causes, and by precept and example lend every influence toward their removal.

From the foregoing it is apparent that the main object of our work in this direction is to provide the best medical service possible for the mentally afflicted individual, within or without the hospital.

The State should establish at every institution a department fully equipped for scientific work. I say at every institution, because with me the basic principle of this movement is the creation of centers around which the members of the local profession may gather and study mental and nervous diseases, their causes and treatment.

Again, I believe in encouraging individuality, and know that a State can well afford, in view of the great benefits derived, to have a number of investigators pursuing original and independent work in this cause;

and last, but not least, I contend that each and every institution, with its medical staff. is entitled to equal advantages and equal opportunities.

In conclusion I extend to each and every member of the Academy a cordial invitation to visit this department and inspect the equipment and the methods pursued.

# An Addition to the Birds of Indiana.

By Amos W. Butler.

Harris Sparrow.

*Zonotrichia querula* (Nutt).

A specimen of this western species was taken May 4, 1907, near Sheridan, Hamilton County, Indiana, by Ernest P. Walker. It is an adult male in good plumage and was found along a hedgerow in company with White-crowned Sparrows. The time of capture was about noon. The day was rather cool and the birds were hopping about near the ground. It was not at all wary and was shot at close range. No others of this species were observed.

Mr. Walker has kindly presented the specimen to the Academy and it has been deposited in my collection as a verification of this record.

Harris Sparrow is a bird of the middle United States. It ranges from Illinois over the central plains and casually to Oregon. It is reported as a rare winter visitor in Illinois and Wisconsin. (Ridgway, Ill., Orn., I, pp. 266-7). One was taken near Riverdale, Ill., October 6, 1894, by J. O. Dunn (Butler, Birds of Indiana, 1897, p. 1178).

# Biography and the Influence of Environment.

By Robert Hessler.

Biography concerns itself with 'the history of the life of a particular person.' This is the primary definition given in the Century Dictionary, a second being 'biographical writing in general, or as a department of literature.' Again as a third definition, 'In natural history, the life-history of an animal or a plant.'

Biology, on the other hand, concerns itself with the science of life and living things; with a knowledge of vital phenomena; in a technical sense, the life-history of an animal.

Environment is another name for surroundings, and environmental influences may be regarded as the influence of surroundings.

In speaking of the evils entailed by the lack of knowledge of surroundings, Ward in his Dynamic Sociology says: "Indeed, the greater part of all suffering is the result, direct or remote, of such ignorance. Obviously, therefore, the first great duty of man is to acquaint himself with his environment. This can only be done by study. The phenomena that lie on the surface are of little value. They mislead at every turn. Not only must the deep-lying facts, difficult of access, be sought out with great labor and perseverance, but they must be co-ordinated into laws capable of affording safe and reliable guides to human operations. To do this requires a vast amount of patient study. Only a little has yet been revealed of the more important truths of nature, yet consider the amount of research which it has required! Nevertheless, only a few individuals have contributed any thing at all to the result. It is as yet only the simpler and more obvious relations between man and nature that have been determined. In the domain of physical forces and chemical substances he is able to exercise prevision in many ways to secure advantages and avert evils, but in most of the higher fields of vital, mental, moral, and social phenomena, these relations are either utterly ignored or but dimly suspected, so that his knowledge of them avails him nothing. The great work before him, therefore, still is study." (Ward, Dynamic Sociology, Vol. II, p. 11.)

Ward further says: "But what constitutes the environment of the civilized man? The character of the environment of animals and of savage man is easy to perceive. It is the earth, the air, the rocks and waters, the trees, grass, birds and animals, the last to include, in the case of the savage, the men of his own tribe and of other tribes, and also civilized races, in case any such ever come in contact with him. It is by learning to know these things that he is enabled to protect and defend himself.

"But, looking to races somewhat more advanced than the crude savage, we find, as frequently shown before, that their advancement has been due to action on their part in taking advantage of certain deeper laws of nature, in making use of materials that savages fail to make use of, in interpreting phenomena that savages do not correctly interpret, and, through these means, in devising plans and inventing appliances for multiplying the products of nature and increasing the supply of physical, social, and intellectual wants. And, when we have reached the highest forms of social existence, we find that the only effective means by which desire is gratified, progress achieved, and happiness attained, consist in still deeper knowledge of the natural surroundings, in a still wider grasp of laws and principles, in the correct interpretation of still more obscure phenomena, and in the discovery and invention of still better means and methods of securing remote ends. To know one's environment is to possess the most real, the most practical, the most useful of all kinds of knowledge, and, properly viewed, this class of information constitutes the only true knowledge." (Ward, Dynamic Sociology, Vol. II, p. 495.)

In discussing the expression 'knowledge of the environment,' Ward comes to the conclusion that it is co-extensive and synonymous with the word science. He says: "Knowledge of man's environment is nothing more nor less than scientific knowledge; and, conversely, all scientific knowledge consists in knowledge of the environment * * *" (Vol. II, p. 497). Farther on he says: "The only useful knowledge is that which furnishes relations. Isolated facts, until employed for this purpose, are not really employed at all. An object known only in itself can scarcely be said to be known. * * * Science is dynamic. Whatever it touches is transformed. The only object in knowing is by means of it to do something * * *." (Vol. II, p. 497).

He refers to the attenuation of knowledge and of getting away from things, and how especially in the Middle Ages men were inclined to neglect facts, and how science brings us back to facts and to nature. We can

readily see how students of environment and environmental influences are not likely to be misled by the present fad of psychotherapy. Ward also refers to much of our literature as being simply a jugglery of words, pleasing to the ears, but of little value in keeping man acquainted with his environment.

Perhaps few of us realize fully the importance of environmental influences, of how our life and our very thoughts and actions are dependent thereon. No doubt many of us have at times wondered what our own life and the life of others would be under different surroundings.

The field is a large one, and by way of delimitation I may say that my original observations and studies are confined largely to one phase of the subject, that of air conditions. The problem is this: To what extent do the effects of air conditions crop out in biography? To answer this requires, first a study of men who are today living under good and bad air conditions; it means to contrast lives of men, those who live under good air conditions with those living under bad air conditions; it requires, moveover, observation of individuals who alternately live under good and bad air conditions. Secondly, it requires the 'fossil remains,' so to speak, which can be studied, just as the paleontologist studies fossil remains which enable him to reconstruct and explain past animal life—the material in the present instance being biographical remains, books that are often known under the name of Life and Letters, as those of Huxley and of Darwin.

We all like to read about great men and emulate them; their lives are held up as examples to follow, yet the number of great men living at any one time is small, and where one becomes great, there will be thousands and thousands who are mediocre. A biographer scarcely deems it worth while to pick out the life of one of this latter class.

It may be entertaining to the average man to read the biography of a literary man, of a poet, or of a musician, but he may get comparatively little instruction from it. On the other hand, he may read the life of a common fellow citizen and get many ideas that will be of value to him in the conduct of his own life. This is a fact that seems to be little realized by biographers, but it has been appreciated by certain novelists who write about the common people, and such books are therefore very popular. Formerly novelists were concerned chiefly with the life of the 'upper classes,' but since they have begun to write of the 'common man,' to depict his life, we now know that such 'lives' can be made of general interest.

Likewise, in former days, the physician was concerned chiefly with the well-to-do; the diseases and affections of slaves and agricultural laborers and artisans were given little attention. Today distinctions are of course still made between the literate and the illiterate, but there is a very large class between these extremes—the common people, and writers have this class of readers in mind rather than the small cultured class.

Some one has said that under each grave lies a world's history, and in this light the life of the most common-place man would likely reveal many incidents that are worth recording, both on account of their general interest and the lesson they may teach.

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In the course of years I have accumulated many notes and 'case reports,' that is, histories of individuals in chronic illhealth. Some of these histories cover the individual's whole life, from beginning to end, and if published would be biography, but since they relate to illhealth and give a minimum of facts in regard to other affairs of life, such a biography would be of interest primarily to physicians, to biologists, and individuals in chronic illhealth who might profit by the experiences of others. A wise man has been defined as one who profits by the experiences of others; a fool as one who scarcely learns from his own.

My paper is to be considered as a continuation of papers given in former years before this Academy, but to fully understand the subject, this series of papers should be considered in connection with another series given before the State Medical Society.

I have prepared a number of case histories, more or less briefly, in the form of long charts which I shall show with a few remarks on each. (Charts on rolls and diagrams were shown, the following notes being abstracts.)

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BIOGRAPHY A. The environmental influences crop out very strongly in the family history, as shown in the genealogical table. The ancestry goes back into early colonial days, and until now the members have always lived under rural conditions. The great-grandfather's generation was a long-lived one, likewise the grandfather's and the father's and his own also, that is, his brothers and sisters; ten to twelve usually constituted a family. The individual himself until recently had always lived on a farm and led an active life. He had good health, but when he

came to the city his health began to fail, ascribable to 'change of air.' To stand on a street corner in a 'spitter's town,' with clouds of dust blowing about, is a rather risky occupation. His children show an entirely different history from that of the ancestry, a long life history being displaced by a short one. The children die of the 'diseases of civilization,' and that means chiefly a bad sanitary environment. The offspring, instead of living to the age of sixty, seventy, or eighty years, die prematurely, eight out of twelve dying in childhood.

Judging by or from the ancestral history, one can predict what the final termination in this case will be. One can predict—as well as that can be done in complex biological predictions. Recently the man had a cerebral apoplexy which disabled him for a time, but he gradually recovered; a continued high blood pressure means that before long there will be another apoplexy, in fact there may be several, until one is sufficiently severe to carry him off.

Some of my case histories cover a period of only a few years, but where much attention has been given, the thoroughness of study may offset the length of time. One can readily see that if an observer were to devote his attention, say for only a year, to the study of the life of an individual in chronic illhealth, much might be learned, more than where one attempts to cover an individual's whole life in a superficial manner, and we can readily understand how a physician with many patients to look after can so scatter his attention with so little time for each that he simply cannot do his patients, or the subject, justice.

People in health scarcely know what illhealth means to one who has 'chronic illhealth,' where the subject necessarily is more or less constantly in mind, and that certain symptoms—symptoms of illhealth, indicative of a reaction to a certain cause or to an abnormal environment—are present all the time, every hour of the day, and from one day to another.

The individual in chronic illhealth naturally seeks relief; he applies to the physicians, and if the physicians do not understand the case and if no good results follow their treatment, the individual naturally applies elsewhere. Some chronics are constantly drifting from one physician to another and from one form of treatment to another, even the most outlandish. In the last month one of these 'chronics' came to me. On critically studying the case, I found that she reacted to her environment, that is, in this case, to dust influences. The patient was intelligent; she promptly acted on my suggestions and many symptoms gradually vanished;

others were greatly modified, both in severity and number. One day, after the patient had been with me for some time, she told me that I was the eighteenth physician she had consulted. This individual could write a book on her experiences among doctors, and it might make painful yet beneficial reading to many who prescribe purely on a statement of symptoms.

BIOGRAPHY B. Next in order would come a history, a biography, in the making, of a bright boy of fourteen years, but for certain reasons it was thought best not to put this case in the form of a chart. This boy reacts to his environment, but the chronic illhealth under certain conditions promptly subsides under other conditions. At the International Congress on Tuberculosis, at Washington, two months ago, Dr. Koch made a statement which I have repeatedly verified. He said it was very important to teach school children the important facts connected with tuberculosis, that they will learn readily and remember, whereas the old learn with difficulty and forget readily. I have frequently met elderly people whom I attempted to instruct, but after a time I would ask myself, What is the use? One is apt, on the other hand, to take unusual pains in instructing the young and intelligent, who are both willing and capable, and it will be interesting to read the biography of an individual who keeps a daily record of what he does and where he is, and of the conditions relating to health and illhealth.

The question at times arises: Should an individual in chronic illhealth be asked to keep a daily record of events and of symptoms? I have had persons tell me they had so many symptoms that it would be impossible to keep track of them—yet in a short time there would be only a few to record, if they heeded rational advice. When the sick begin to realize that there is a relationship between symptom and cause, they no longer lie awake at night 'wondering what it all means.'

One can readily understand why the individual brought up in the country under good air conditions should suffer on removing to the crowded city, and why the individual who is chronically ill in the crowded city may quickly regain health on going to the country, or by merely exchanging a dirty city for a clean one. We can also see how a study of biography in the light of air influences, of coniotics, so to speak, may be both interesting and profitable.

BIOGRAPHY C. The influence of environment crops out in several ways in this case, a man of 57. His father and mother were Irish; he was picked up as a waif in New York City when a small child, and, with

a number of others, was sent West; he reached Indianapolis and was adopted by a German Protestant. To see the man now and to speak with him, one would never suspect that he is Irish, for he seems to be a thorough-going German, with all the German characteristics. As one might expect, he adopted the religion of his foster parents. Some one has said that our very thoughts and actions are determined by our environment, and this man is an exemplification of it. In a general way, it may be said that the Irish in their own country live mainly under a rural environment; when they come to our crowded cities many fail. This man seems to have gotten along fairly well in his earlier days, but there has gradually developed a greater and greater susceptibility to city environmental influences.

When this man first came to me five years ago, he thought his sand of life had run down, and on superficial examination I was inclined to agree with him, but when I studied his environment and past history, I came to a different conclusion. I saw no reason why he should not continue to live for a number of years. In explaining the condition to him, I referred to Huxley and how he reacted to his environment and yet lived to the age of 75, and might perhaps have lived still longer had he known more about the influence of environment. I mentioned the English saying, that in order to live long one should acquire an incurable disease, explaining what is meant by 'disease'—that it is really no disease at all, simply a reaction to environmental influences: that the pains and aches, the warnings of nature, could be prevented by avoiding the cause, and that means to observe and to seek to avoid them. In proportion as causes are avoided, one may live on and on. It took some time to fully explain matters to him and to induce him to give up his occupation, an indoor one with dusty air. There was a constant tendency to high blood pressure, and I explained the danger of 'bursting the boiler,' but he continued until he 'burst a pipe,' that is, there was a break of a small blood-vessel in the brain, resulting in slight apoplexy. The break occurred in the speech center and temporarily rendered him speechless; fortunately the effects passed off in a day or two. This was a warning which he heeded; shortly after he abandoned his occupation and lived out of doors. But he could not live indefinitely without work, and in a 'spitter's town' the number of occupations attended by good air conditions are limited. He finally obtained employment in a hospital, as attendant. Here the air conditions are good and now he is getting along very well—as I had predicted.

One can of course see that when an individual has spent years and

years under an unfavorable environment, structural changes may have been produced—we need only think of inflammatory processes followed by the formation of scar tissue—and that the outlook for a long life is not as favorable as in the case of a young person who gets out in time and before many organic changes have occurred or much scar tissue formed. In this case, it is not so much a matter of living a long life as it is of the subsidence of chronic illhealth and the ability to do a 'fair day's work,' to make a living instead of being dependent on charity.

It will be noticed that this biography is in several sections:

1. An outline of his life, by years, in the form of a chart.

2. A detailed statement up to the time he came to me, in loose sheets.

3. A statement of his observations since he has been with me. It will be observed that all are autobiographic—that is, written by the individual; they were given me in the belief that his experience might be of benefit to others.[1]

4. My own observations briefly summarized and charted, with sphygmograms here and there showing circulatory conditions. In the light of other cases, one can predict that this individual will, in all probability, ultimately die from heart and renal trouble. In a general way, one can divide men into two groups, high pressure and low pressure; each group has certain symptoms.

BIOGRAPHY D. It is only occasionally that one is able to get a complete life-history, that is, from beginning to end. I shall show one of this kind. The long sheet gives an outline of incidents, arranged by years (of factors which the individual, more or less conversant with the subject of dust infection, considered of sufficient importance to be noted). The details that I asked for concerning certain factors, incidences and occurrences, are given in these notes (shown). This individual was with me for only a short time, barely long enough to study her history and condition. She died some time later after having been under observation of two non-resident physicians. The influence of environment crops out all through this history, or strictly speaking, biography. The influence of life in the large city or in the country can be clearly traced. One environmental influence may be especially mentioned: This individual went to Korea as a medical missionary and there contracted a tropical disease from which she ultimately perished. One can readily see that had

[1] The number of individuals who will allow the history of their lives to be used, as here presented, is rather limited—it takes the "missionary spirit" to do that.

she not gone into the environment under which foreign diseases flourish, she would not have contracted such a disease. Missionaries are a self-sacrificing class of individuals; popularly it is often believed that they break down on account of overwork, but one can look at it from the standpoint of a change of environment—and this may lead us to critically study a case of overwork in our midst; perhaps after all it is simply the influence of environment. It may not be so much a question of the amount of work done as where the work is done. One may seriously question whether our school children break down from 'overwork'—perhaps the defenses of the body in fighting off infection, bad air, are overworked.

To study the life-history of any one case is a task of magnitude. There are many details, and the more factors one considers, the greater the number of details that have to be studied. An individual in chronic ill-health may complain constantly; all his symptoms and all his complaints have a cause; they must have a cause. To what extent can or does the student physician take up such details?

There are few physicians who have many patients whose lives they can study from beginning to end—and to study a long life is wholly beyond a single man's opportunity, because the physician, the student, is already well advanced in years before he has the requisite knowledge to make such a study. He must begin with the individual at birth, and if the latter has a long span of life, the physician will be dead long before his patient. To properly study the subject requires co-operation of many men.

Biography is valuable chiefly in that it teaches us how to conduct our own life, that is, we can profit by the experience of others. Moralists like Samuel Smiles will take a biography and from it teach certain lessons (Prudence; Self-help; Industry; Forethought; Self-reliance; etc.), but the idea that the illhealth or sickness of a man may teach us how to avoid similar experiences has scarcely been considered and to the best of my knowledge not at all in the light of good and bad air conditions.

Many biographies contain so few references to health and illhealth and disease that one might come to the conclusion that these were things not worth mentioning; very few are satisfactory to the student. Personally I have never met one that gave all the details I wanted.

The individual who is influenced by his environment manifests certain symptoms. Some of these symptoms can be grouped, and one can speak of types. Some part of the body or some organ may show the reaction in

a marked manner, and in this way determine the type. Thus, one can speak of a respiratory type of dust infection, of a gastric type, of a nervous type, etc. In some there is no localization; the body as a whole reacts. There may be a large number of symptoms and yet there is nothing definite that would enable one to speak of disease. It would appear that the body is really 'healthy' but is simply reacting to the abnormal environment, and the moment the environment is changed, the symptoms disappear.

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I have made a search through biographies relating to Indiana people for a good example of the influences of environment. I found only one biography that is sufficiently full to enable one to trace such influences, but as I am in search of further data, I shall not take this up at present. Instead I will take up the Life and Letters of Huxley.

Thomas H. Huxley. The life of a man like Huxley or Darwin can be written from many different standpoints. If the biographer is a naturalist, he can bring in the development of Natural History that has taken place throughout the long life of such a man and the prominent part he took in it. If an evolutionist were to write the life, he would likely treat it from the standpoint of the development of the theory of evolution in which Huxley took such an aggressive part. The geologist, the paleontologist, the ichthyologist, etc., each would find material enough to write a work that would be of interest to the specialist. The physician likewise finds material enough to write what may be called a medical biography, of special interest to physicians, and more especially because Huxley began life as a physician and throughout his long life was associated with medical schools and with the best medical men of England. An individual in chronic illhealth can learn much by carefully studying Huxley's Life and Letters, on account of the many references to chronic illhealth. Such a study may enable him to avoid many of the common symptoms of illhealth, or at least to reduce them to a minimum.

Huxley reacted strongly to his environment, and to understand this one must study the lives of people living today who react in a similar manner. Analogy enables us to bring together cases of the same type. In studying the life of a man no longer living, one is in the position of the paleontologist who studies the fossil remains and thereby is enabled to more or less accurately reconstruct for us a picture of the thing that once was living, as already mentioned. According as a biography contains many references to illhealth conditions, one is enabled to more or less fully

understand the nature of the illhealth—which may not have been thoroughly understood during the life of the individual.

Huxley was a voluminous writer along many lines, chiefly, as most of you know, on biological subjects. Beginning with papers on certain groups of animals, he gradually branched out to include man, not only from a biological and anthropological standpoint, but also from that of biography; to understand his many-sided mind, one has to read his various volumes.

To the student of dust influences there is likewise much of interest, not so much in his technical writings as in his biography. Although Huxley realized the general influence of environment, he seemed not to have realized the influence of dust conditions, of coniotics. One can readily see how such a gifted man might have avoided much illhealth, and perhaps have lived many years longer, by having such a knowledge.

Huxley was eminently sane in his views regarding man's position in the universe; unfortunately for medical science, he did not follow medicine closely. He distributed his mind among many fields of inquiry, some of which have only remote relationship to medicine.

At the time when he was actively engaged in the practice of medicine, there was little science compared to what is found today; it was before the days of cellular pathology and bacteriology. Conditions were such as to create disgust in a scientific mind like that of Huxley, and so it is very natural that he should have drifted away from the practice of medicine and become a teacher of some of the sciences on which medicine rests, notably anatomy and physiology.

Although cellular pathology arose during Huxley's lifetime, yet he never took it up. It is an exemplification of the saying, "You can't teach an old dog new tricks," and when a man's eyesight begins to fail on account of age, the days for close microscopic study are past. Unless one studies pathology and bacteriology in the laboratory, makes his own cultures and examines them, one's knowledge is not apt to be thorough and the difficulties of working out certain problems are not realized, and, on the other hand, the brilliant results obtained by some men cannot be fully appreciated. It is only the student who works 'in a practical manner' who gets the best insight, assuming of course that he has the mental capacity also to reason on the 'imaginary or theoretical side,' to form theories and then attempt to verify them.

Huxley did not understand the influence of air conditions. At one

time we hear him exclaim, "I do wish I could sometimes ascertain the exact *juste milieu* of work which will suit, not my head or will, *these* can't have too much; but my absurd stomach." (Life and Letters, Vol. I, p. 131). Herbert Spencer voices the same sentiment when he says, "I want a keeper to be always taking care that I do not overstep the limits on one side or the other * * *."

We need not be surprised that Huxley and men of his type did not understand the influence of air conditions, when we consider that the best medical men, active practitioners of medicine, did not understand it. The two most eminent physicians contemporary with Huxley were undoubtedly Dr. Andrew Clark and Dr. Henry Thompson. These men were constantly sending their patients away from London. Dr. Clark used to say, "What you need is rest, pure air, cheerful companions, simple diet, and no end of out-doors." They got results, patients improved, but they did not press their inquiry and seek the reason why. One can of course readily excuse them for the same reason upon which Huxley must be excused—They began work before the days of cellular pathology and bacteriology and did not take it up in their old days. Perhaps needless to say a knowledge of pathology and etiology is one of the absolute essentials in studying dust infection.

Huxley had a rural ancestry and that means that there had not been an active weeding out through urban influences. When he first came to London as a young man he seems to have gotten along fairly well, but in time there was a greater and greater susceptibility to unsanitary urban conditions and he reacted to his environment. He lived in the West End where air conditions are good, and lectured at Kensington, which, as some of you know, is situated half way into the heart of the city. At first he could lecture several hours a day without difficulty, but after a time he complained that he could only bear one hour and that two hours 'does him up.' Still later he was not able to do even an hour's work under bad air conditions, but when he removed from the city and went to the South Shore, he was again able to do an almost unlimited amount of work.

SYMPTOM NAMES. (Chart with all symptom names grouped was shown.) In looking over this formidable list of names, a few facts stand out.

1. There is only one name that refers to a definite disease, that is, a disease with a specific cause: Influenza.

2. Many of the names are very indefinite, or, one might say, they are just as definite as the conditions to which they refer, and where a thing is indefinite, one naturally cannot expect a definite name.

3. There was no 'organic disease' (until the very end), and some of the names and expressions used were later on found to be erroneous. Take, for instance, the terms relating to the heart, 'dilatation,' and 'enlargement.' The diagnosis was made at a time when Huxley was feeling bad and he was therefore sent to Switzerland. But he began to feel better almost as soon as he got into the good mountain air—and then he began to climb the mountains. Offhand, one would be inclined to say that that was a very foolhardy act, because he might have fallen off the mountain, or dropped into a crevice, and no one would have known what had become of him; but he felt he could climb, and he did climb higher and higher day after day. Then one of the English physicians made him a visit and naturally examined him. Huxley says, "H. Thompson treats the notion that I ever had a dilated heart with scorn!" and then adds, "Oh these doctors; they are worse than theologians." But when he returned to England his old complaint came back. Evidently, however, he had the satisfaction of knowing that he did not have organic heart disease.

With increasing years there was an increasing reaction to an unsanitary environment, he could spend less and less time in the crowded city, finally he had to leave altogether. One wonders why Huxley did not leave the enervating city life and retire to the good air of the country, as did Darwin.[1]

What do we mean by health and illhealth and disease? A man may complain of illhealth and yet not be diseased. As a matter of fact, we constantly meet people who look the picture of health, but on studying them we find that they are always suffering, yet on account of their 'healthy' appearance, they get no sympathy when they do complain, and so many do not complain—only to the physician who critically studies conditions.

Many of these individuals are simply out of harmony with their environment. If we take a native of the torrid zone and put him in the frigid zone, we would likely find him complaining constantly of the in-

[1]Charles Darwin reacted to his environment, after the manner of Huxley. Some of you may recall my paper before this Academy several years ago in which I aimed to bring out this point. But Darwin lived in isolation and came little in contact with sick people, and his symptoms are even less well defined, although he complains almost constantly and loses much time. Getting a lot of old books from the city and reading them while reclining on a couch are among the important factors in Darwin's ill health.

fluence of cold, of a condition to which he was not accustomed and perhaps wholly unadapted. If, on the other hand, we take an inhabitant of the frigid zone and put him in a warm country, we would in all probability find another series of complaints. In the temperate zone where there is an alteration of heat and cold, one might say six months of tropical life and six months of arctic life, many individuals cannot adapt themselves to this semi-annual change, and as a consequence they suffer.

Again, the individual who has been brought up on plain, substantial food in the country, free from all infectious matter, may complain greatly if confined to the food obtained in the city, which has passed through many hands. The milk which so well agreed with him in the country may be a veritable poison to him in the city; even the drinking-water may disagree.

We see this again illustrated in the matter of air conditions. The man who has always lived under good air conditions, and whose ancestors have lived under such conditions, may complain greatly on removal to a dirty city where the air is loaded with dust derived from different sources, partly from the bodies of those who are diseased. Such an individual may have a sound body and may have sound health under his proper environment, but he may complain in the city simply because his body reacts to the abnormal environment. Thus, if he inhales much dust, there may be cough—nature's way of getting rid of offending material. The dust may set up a profuse flow of mucus, resulting in so-called catarrh—and yet this may be simply a natural reaction of the body in protecting the respiratory organs and in getting rid of the inhaled dust particles, which are brought up with the mucus in the process of coughing and hawking. Various pains may come on, yet they are to be looked upon as warnings from nature—to change the environment. When an individual does change and finds all these symptoms of illhealth (not of real disease) disappear, that ought to clearly indicate to him the conditions under which he should live. If he persists in living under the abnormal environment, we know what will happen: nature is constantly weeding out the unadapted—a process that has been going on for countless ages, and still continues. The doctrine of the Survival of the Fittest is a terrible reality from the standpoint of the biologist and physician.

One may come into a new environment and discover that there is a non-adaptation. The thoughtful man will see two courses open; first,

to modify his environment and make it fit to live in; second, to abandon the environment and go into a better one.

To what extent shall one make efforts to modify his environment, to improve it? How early or how late shall one abandon efforts? These are questions of varying importance in the life of all. There are many factors to be considered. With some it is an easy matter to 'pull up stakes,' as the race did in its pastoral stage. The very evolution of the race, from a wandering life to one anchored, so to speak, to a city environment makes it difficult for the average individual to leave the crowded city and go back to the more primitive country life. We need only read the pathetic letters of Mrs. Carlyle with her chronic illhealth in smoky London, but with good health in her old country home in Scotland. She evidently realized relationships and made many trips to and fro, but after being accustomed to London life and meeting congenial people, it was next to impossible to go back to the monotonous life in the country. We thus see that physically she needed one sort of environment, that of the pure air of the country; mentally she required the contact of kindred minds, to be found in the large city.

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What we get out of a book depends largely on the interest with which we take it up and on our previous knowledge. We get out of it what we put in. A book in Greek or in Science will be understood by comparatively few, in contrast to the many who read and understand a popular novel; even 'problem novels' are not always understood. By observing a man turned loose in a large library one can arrive at certain conclusions.

A biography may be so simple that most any reader can understand it. The biography or life of a military man is full of descriptions of battles, best understood by old soldiers; the life of the musician is apt to be full of technical musical matters and best understood by musicians; the scientist best understands the biographies of men of science. The individual in chronic illhealth will likely be the most appreciative reader of the biography of a man who had chronic illhealth—and the physician who studies the subject from a biological standpoint will likely be the one who not only appreciates, but understands such a life and the influence of environment.

If I can induce some of you to read biography in the light of environmental influences, especially of such a man as Huxley, then I shall have accomplished all I had in mind in beginning this paper.

# Felkner Island, Wabee Lake, Kosciusko County, Ind.

By J. P. Dolan.

Wabee Lake is in Kosciusko County, Ind., about one mile southeast of the town of Milford. A good description of its physical features is given by Prof. Blatchley (State Geological Report for 1900, pages 186-7). Quoting therefrom—"A small and very pretty island occurs in the southeast of the lake." When Profs. Ashley and Blatchley visited the lake, there was so little of the island above the water line that a title was deemed needless. However, the protracted drought of the past season has shrunken the lake away from the island, showing it to be of sufficient dignity to bear a title, temporarily at least.

"Felkner" is the name of its former owner and is associated with the best history and development of Milford and its environment.

The island at the highest point is six feet above the lake level and has a dry area of about one acre. It is destitute of vegetation save for a few tufts of stunted willows, a scraggy sycamore about five feet high, a small patch of Canada thistle numbering about twenty individuals, and five or six strong stalks of evening primrose besides a few species of grasses.

Its general appearance is that of a coarse, undisturbed gravel bed. Theré is no field of shallow water upon it. Its sides slope abruptly into water twenty-five to forty-five feet deep. One can stand at the water's edge and with an ordinary cane pole fish in deep water. This body of deep water extends almost to the shore on the north and west, while on the south and east it is found to be a few feet shallower. Taking a radius of five hundred feet and the island is surrounded by water forty feet deep. Thus Felkner Island is removed from shore influences.

In 1906 the Sandusky Portland Cement Company which is operating a cement mill at Syracuse, a town six and a half miles east, became the owners of the island. To satisfy themselves of the extent, character, and distribution of the marl and clay said to be found there, a careful survey was made of the lake, the island, and the adjoining marshes. The lake was cross-sectioned at intervals of 100 feet. At these several points

thorough tests were made measuring the depth of water, marl, muck, clay or other minerals that might appear. In making these tests a drill capable of being extended to forty feet was employed.

The general distribution of the marl and other minerals around the *shore of the lake and the territory adjoining* is reported in the Volume of Geol. Reports for 1900, fully and accurately.

The island, as far as could be determined, is a unit of granular marl. The 40-ft. drill failed to reach the bottom of the deposit at several places. The marl is accounted for by the presence of several strong springs at the west end of the island. One of them, about four inches in diameter, issuing at a point where the water was six inches deep, would push its way up intermittently so that one could see the disturbance at the surface standing a hundred feet away. These springs, doubtless have their origin in the clay and gravel hills near Dewart Lake three miles to the east and bring their burden of calcium carbonate from that rich field. This theory is borne out by the presence of a flowing well at the east end of the lake at an elevation thirty feet above the level of Wabee. It flows strongly through a two-inch pipe and reliable men of the town who tested its force say that it rose twelve feet above the present point of escape through a pipe of smaller diameter. It is known that Dewart Lake has an elevation of fifty-two feet above that of Wabee Lake.

The Mollusca found in the island deposit, below the upper portion thereof, are only a small fraction of the whole. This is all that distinguishes this island from the many other "beautiful" spots dotting the lakes of Northern Indiana, but it is a fine type of the island formed by springs. The Syracuse & Milford Railway transports the marl to the factory, delivering daily from four hundred to five hundred cubic yards. The small steel cars are loaded on the track by the dredging apparatus, an improved clam shell excavator having a 75-foot boom. Felkner Island will be loaded on the cars with the present dredging machine, pontoons being employed to carry up the train from the island to the shore.

Involved in this matter of removing the marl from the lake is the question of its effect upon the flora and fauna of the lake. This is a question which comes within the province of this association. If an answer is desired a biological survey of the lake should be made at an early date.

# A Strange Nurse.

By A. J. Bigney.

On June 1, 1908, there was born on the farm of Will H. Sedam, near Moores Hill, Indiana, a litter of kittens, only one of which lived. The mother of these kittens died August 1. The surviving kitten began to try to nurse the sire. Soon milk began to flow a little and as the nursing continued the milk increased in its flow. The sire soon had two well developed nipples doing service. The kitten lagged a little in its growth for a while, but soon was in good condition and continued to do well. This is the first instance of the kind that has come under my observation.

# The Shake Dance of the Quilente Indians, With Drawing by an Indian Pupil of the Quilente Day School.

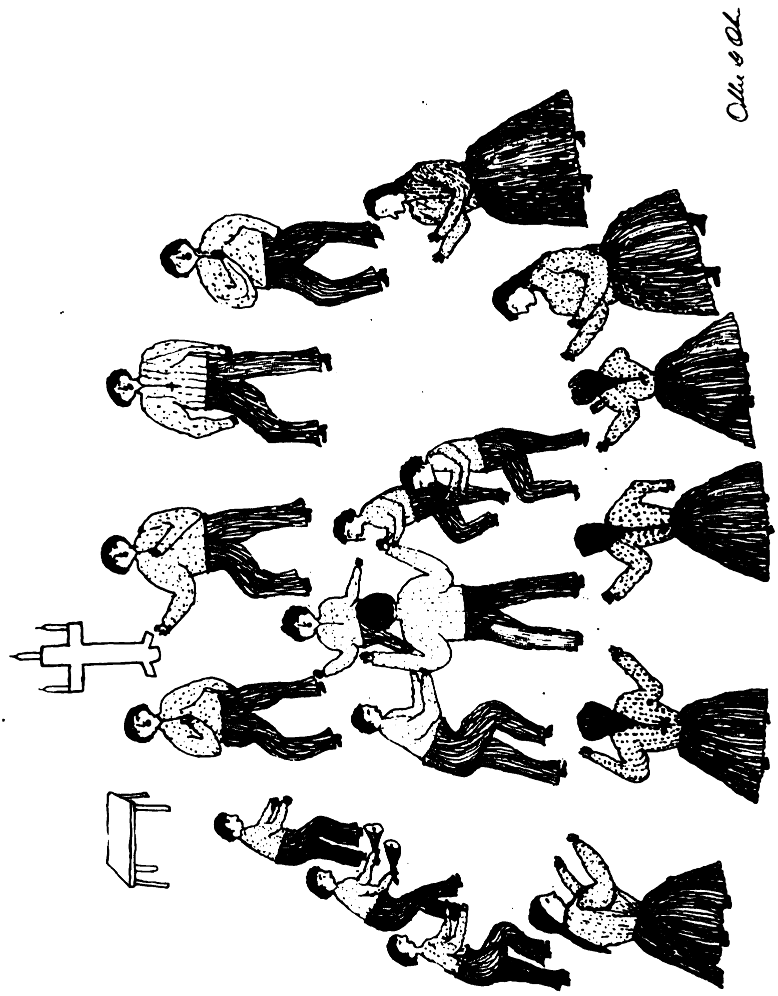
By Albert B. Reagan.

In this dance the Indians worship Jesus, calling Him Jesus-Man, confounding him with Kwatte, their god. This religious movement began in the early eighties. It is a compromise between the old Indian worship and Christianity. The former having been forbidden by the government, the Shaker "church" was organized so that the Indians could still have their performances under the constitutional rights granted to all religious denominations. And in this they have entirely won, for Judge James Wickersham, of Tacoma, Wash., fought the Shaker Church case through the courts and obtained for the aborigines the right to worship God according to the dictates of their own conscience.

The movement began on the Big Skookum River, near Shelton, Wash., in 1882. An Indian, John Slocum, was very sick and was unconscious for several days. Regaining consciousness, coming back to "life" again as the Indians say, he said he had been dead and in heaven, but that the keeper of that blissful place had told him that he was a bad Indian and that he would have to go to hell. But one more chance would be given him. If he would go back to earth, lead a good life and teach other Indians to do the same, he would in time be admitted into the happy hunting ground. He at once began to preach the Shaker doctrine, exhibiting the power conferred upon him by those above in a vigorous shaking and quivering of all the muscles of his whole body. And all his followers exhibit their power the same way to this day.

They have candles and usually a cross. They begin their services with a prayer and close them with a "doxology." The Shaker dancing ceremony which usually lasts for hours is a hypnotic performance.

The watchword of the organization is: "Do good to those who do good to you and get 'even' with those who mistreat you." And the guiding prayer "Our God is in heaven. If we die He will take our life to heaven. Help us so that we shall not die. Wherever we are, help us not to die. Our Father who is there, always have a good mind to us."



In the performance continuous hand bells are rung to the tune of the chant "Hi, hi, hi," etc. The dancers jump up and down to the time of the "music." The faces of all the actors become hideously distorted. The quivering, trembling, twisting, writhing hands, wave, whirl, gyrate in all directions till the scene reminds one much of the demons in the "inferno" dancing over a lost soul. And the simple-hearted Indians believe that in this performance they are worshiping the most high God.

Below is a copy of the Quilente Shaker organization, creed, etc., taken from the "Quilente Independent," the only paper in Washington published by an Indian (W. H. Hudson):

PREAMBLE.

In order to form a more perfect union and to secure recognition of our rights under the Constitution of the United States, to worship God according to our conscience, We, the delegates, from the Shaker Sects of LaPush, in conference assembled, do hereby organize, ordain and establish the Shaker Church.

OBJECT.

Our object is to teach the Gospel of Jesus Christ, and to forward His Kingdom among the Indian race; to fight against the evils of intemperance, which we believe to be a detriment to the advancement of our race; to the pursuits of civilization and Christian living.

ARTICLES OF FAITH.

1. We believe in God the Father, Jesus Christ the Son, and the Holy Spirit, the Three in One.

2. We believe that the Shaker movement was a dispensation of Almighty God to His Indian Children, to the end that they may see with spiritual eyes, their evil ways, and to point our way to salvation through Jesus Christ the Son.

3. We believe that Jesus Christ has the power to forgive sins on earth.

4. We believe that God hears our prayers for the sick, and that if we pray and believe, He will heal us of our physical ailments.

COVENANT.

1. We promise to support the Church in all the ways that we can, spiritually and temporily.

2. We promise to accept the Shaker Religion, and hereby consecrate our time, our talents, our all to its maintenance.

3. We promise to abstain from use of all intoxicating liquors.

We, the members of this church, in view of the solemn promises you have made, do promise to help and sustain you in your efforts to live a better life.

4. We promise to pray for you, that God in His Infinite Goodness, may make you and us, worthy to walk in His footsteps, looking forward unto the day when we all stand before His Judgment Seat, equals with all men, and hear the words, "Come ye blessed of my Father, inherit the Kingdom prepared for you from the foundation of the world." Amen.

# Photographic Observations of Morehouse's Comet.

By W. A. Cogshall.

Comet c 1908 was found on a plate taken at the Yerkes Observatory on September 1st and has been so situated as to allow observation from any point in the northern hemisphere for several hours each night.

Most of the comets, during the time they are visible to us, are in nearly the same direction from us as the sun, and so are seen only for a short time before sunset in the evening, or before sunrise in the early morning.

Comet c had a high northern declination when found, and afterward passed within about 16 degrees of the north pole of the sky, so that during this time it was visible all night. As a result continuous records were secured through several hours, from the time it became dark in Europe till daylight in California.

These records show beyond doubt what has been indicated by several other comets—that the tail is composed of matter driven off by the action of the sun from the head of the comet, and that the velocity of motion of these particles in the tail is such that practically a new tail is formed each day.

While this comet was not very bright visually, it photographed very quickly, exposures of an hour with a short focus lens showing from 6 degrees to 10 degrees extension of tail, and it also showed unusual and sudden changes in the details of its tail.

The most prominent of these are shown in the accompanying photographs.

The first of these happened on September 30th. The photograph of September 29th shows nothing unusual in the appearance of the comet, but the next plate whose mid-exposure time was September 30th, 11 hours, shows a great change in the size, direction, and general character of the tail. This change began during the afternoon of September 30th, and by early morning following had produced the appearance shown in the plate of September 30th, 14 hours, 45 minutes.

The great cloud-like mass of tail moved away from the head of the comet at a rate of about 20 miles per second, and on the next evening

(See plate October 1st, 11 hours, 00 minutes) was at a considerable distance from the head, and connected with it by very faint and straight streamers.

On plate October 2d, 10 hours, 30 minutes, it is visible still farther away, and much fainter, and the new tail near the head of the comet is beginning to assume its usual form.

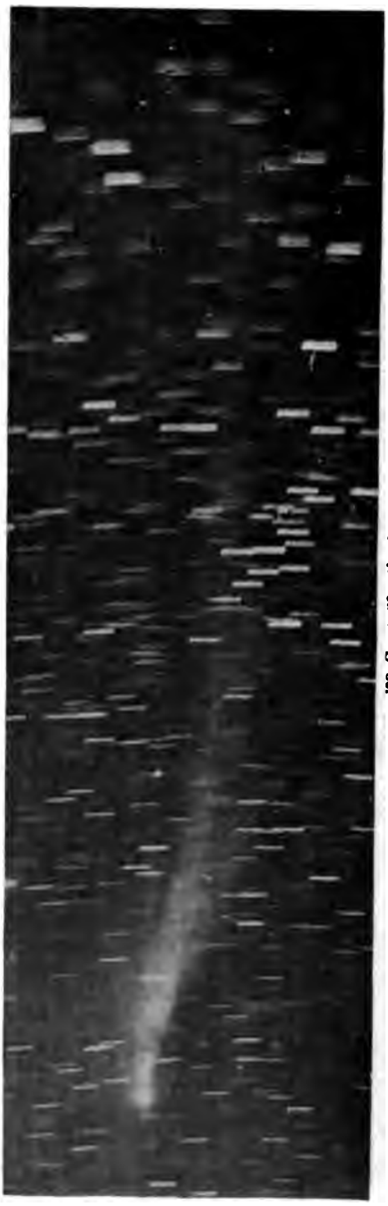
The next great disturbance took place on October 15th. The night before, the comet was quite normal in appearance, as shown in plate October 14th, 10 hours, but on October 15th, 8 hours, a great puff or explosive action is shown.

On the next plate of the same night this is shown at a greater distance from the head, and of a little different form, measurement of the plates giving velocities as high as 70 miles per second.

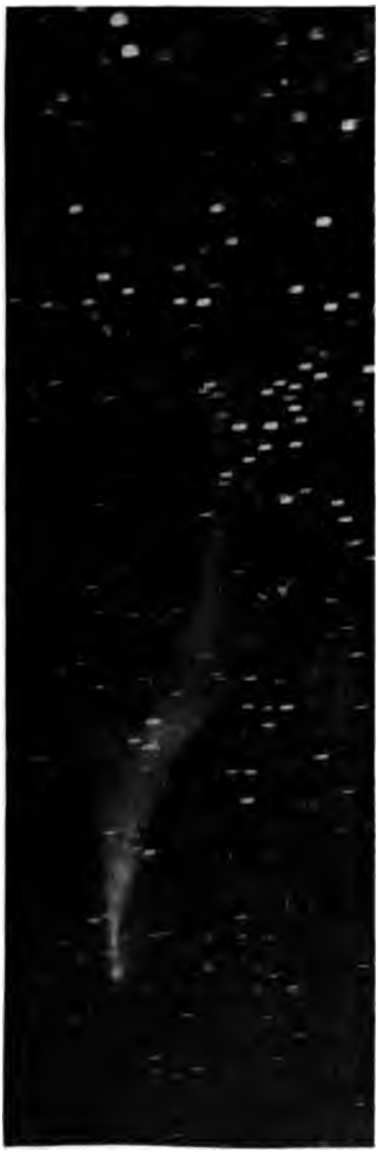
The plate of November 15th, 6 hours, 15 minutes, shows the comet during the latter part of its time of visibility, and when it could be seen for only an hour or two before setting, and shows a great variety of detail in the streamers and condensation in the tail, all of which were invisible in any telescope, and were known only through photography.

About seventy-five plates of the comet were secured in all, and gave a fairly complete history of it from September 21st to December 1st.

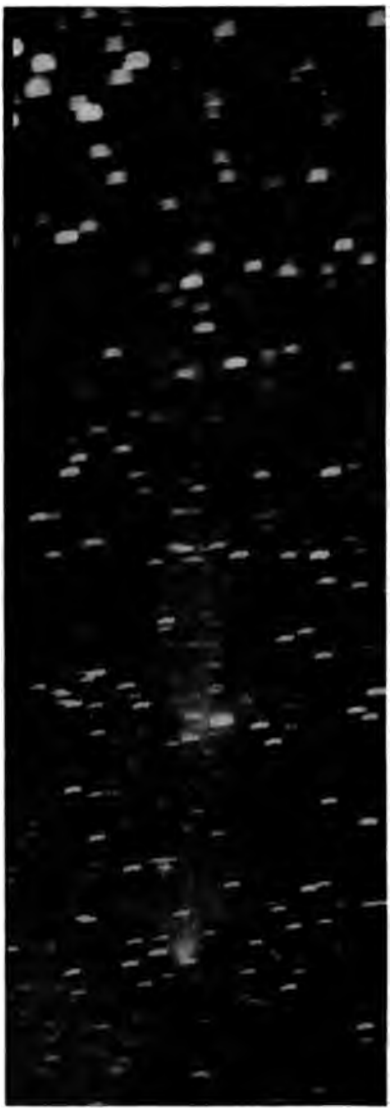
'08, Sept. 29, 9h 35m.



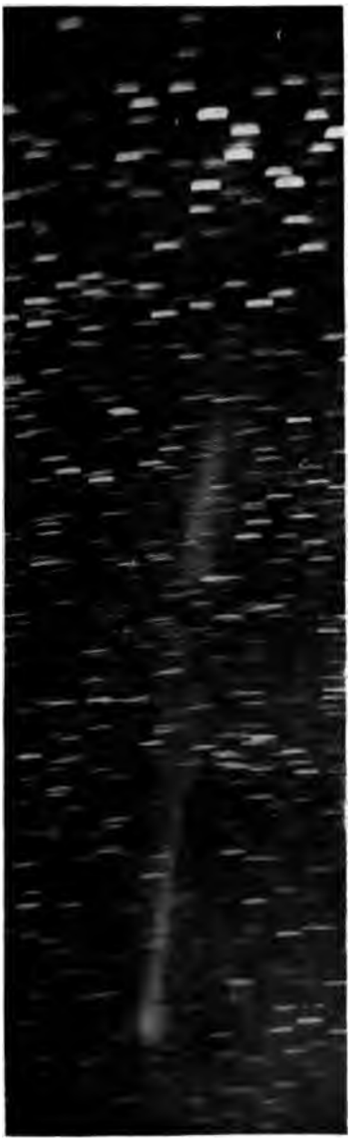
'08, Sept. 30, 11h 00m.



'08, Sept. 30, 14h 45m.

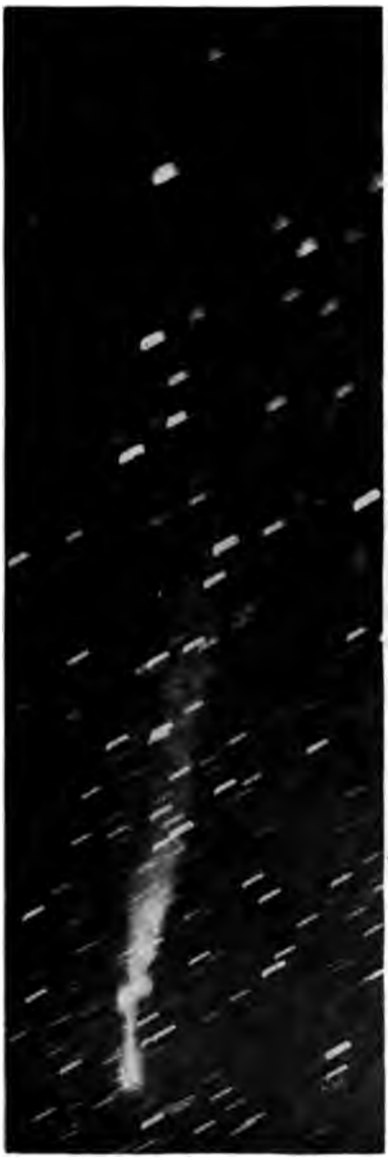


'08, Oct. 1, 11h 00m.

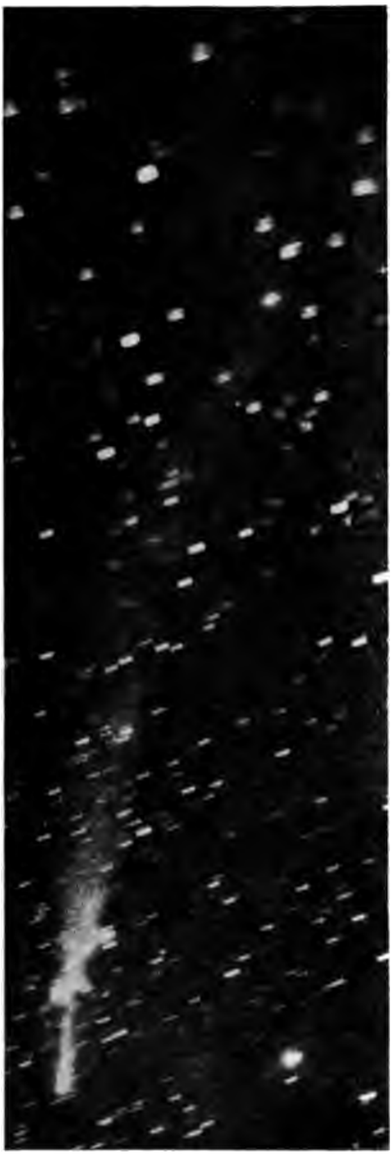


'08, Oct. 2, 10h 30m.

'08, Oct. 14, 10h 00m.



'08, Oct. 15, 8h 00m.



'08, Oct. 15, 9h 35m.

'08, Nov. 15, 6h 15m.

# Field Observations on Rusts for the General Botanist.

By J. C. Arthur.

(Abstract).

The polymorphic character of many species of rusts, together with the discontinuous growth between the forms of most of such species, and the further fact that some species live upon unlike hosts at different stages of their life cycle, make the study of the rusts unusually attractive for those who enjoy a varied problem. A very important part of the field observation consists in later visits to the spot where a rust has been found in order to ascertain if it is followed by another form of the same species either on the same host or on a host of some other kind. In either case, but especially the latter, a suitable specimen of the rust may be taken to a locality where it does not occur and placed beside a healthy plant of the kind observed. It is then watched to see if the rust infects the healthy plant. If it does, the correctness of the inference from the first observation, that the two forms of rust found to succeed each other in the same locality belonged to the same species, is established. But if the healthy plant does not become infected, either the two forms found in the original locality belong to distinct species and only incidentally happen to follow one another, or else the sowing of the rust in the new locality was not well done. In either case further trials and observations are required. There are many variations to the inferential and deductive reasoning required to solve these problems, and to come to a conclusion repeated observations may be required extending over many months or even years.

# The Rust of Timothy.

By Frank D. Kern.

(Abstract).

This paper discusses the importance of timothy rust, showing that it is seemingly increasing in distribution. The results of an investigation concerning its identity and nature are given, followed by a brief statement of what may be expected from it in the future.

# On the Heteroecious Plant Rusts of Indiana.

By Aaron G. Johnson.

In the study of any organism, a knowledge of its life history is one of the things of first interest. Particularly is this true in the study of the heteroecious plant rusts, exhibiting, as they do, alternating phases on entirely different host plants. The complexity, which these plant parasites present, adds varied interest to their study, although the same complexity offers abundant obstacles in determining the connection of the various forms.

It is the purpose of this paper briefly to show what has been done in the way of connecting forms represented in the State, and what remains to be done in this particular line. In presenting the unattached forms, particularly the unattached aecia, it is hoped to help engage the interest of others in assisting in any way possible in properly connecting up these forms. The three lists given below show respectively the connected forms, with the authorities and dates of connection for each species, the unattached telial forms, and lastly the unattached aecial forms. The first two tables are based on Dr. Arthur's Revised List of Indiana Plant Rusts (Proc. Ind. Acad. Sci. for 1903.) For convenience, the familiar genus names *Uromyces* and *Puccinia* are used, the species names, as far as possible, being revised to date. The third table is based on specimens in Dr. Arthur's herbarium, as are also the aecial forms appearing in the first table which have been connected up since the presentation of Dr. Arthur's list. For host names Britton's Manual (2nd. Ed.) is followed. The sincere gratitude of the writer is here expressed to Prof. J. C. Arthur for access to his very valuable herbarium as well as to his extensive library. Most able assistance was also given throughout by both Dr. Arthur and Mr. F. D. Kern, for which the writer is very greatly obliged.

The life histories of thirty-four species of heteroecious rusts represented in Indiana are now known. The aecial stage, however, of nine of this number is not known to occur within the State. In some cases

it may have been missed by collectors, as on Larix, for example, and may subsequently be found; in others, however, it is doubtful if the aecial stage occurs here. In this case the species doubtless depends entirely upon its urediniospores for reinfection of its host from year to year. Such, for instance, is no doubt the case with the Poa rust (*P. epiphylla*) and the leaf rust of cereals and certain grasses (*P. Rubigo-vera*).

In view of these facts it seems very doubtful that all of the sixteen still unattached telial forms in the State have their respective aecia here. In the first place, only nine unattached aecia are reported for the State, though others may occur. In the second place, and apparently much the better reason for the inference, of the thirty-four connected-up species previously mentioned, only twenty-five have their aecial forms reported for the State, while all of the connected-up aecial forms reported for the State have their telial forms here also. This latter being very natural to suppose for the teliospores are not readily transported by the wind or otherwise, and the sporidia, which give the aecial infection, are very perishable and entirely incapable of being blown very great distances and still remain viable. Hence there seems little if any question but that some unattached telial forms come into the State by uredinial infections, and are thus kept up through the season and possibly even from season to season in some cases. The aecia belonging to such forms may, therefore, be far distant.

This condition, then, centers our interest in connecting unattached forms, largely on the unattached aecia. For of necessity, their respective alternate forms must be somewhere in the immediate vicinity of their occurrence, except in the few cases where the aecial mycelium is perennial, in which cases the forms may become somewhat separated. By carefully searching for and finding unattached telial forms, especially near where the unattached aecia occur in abundance, clews may often be obtained that may ultimately lead to proof of the genetic relationship of such forms.

The tables are as follows:

## CONNECTED TELIAL AND AECIAL FORMS.

EXPLANATION OF SYMBOLS USED.

* Cultured in Europe.
** Cultured in Europe, verified in America.
† Form not yet reported for Indiana.
†† Form not yet reported for America.

| | | |
|---|---|---|
| Coleosporium Solidaginis (Schw.) Thuem.<br>(Solidago spp. & Aster spp.) | †Peridermium acicolum Und. & Earle<br>(Pinus rigida) | Clinton<br>1906 |
| Melampsora Medusae Thuem.<br>(Populus spp.) | ††Caeoma sp. (1)<br>(Larix sp.) | Arthur<br>1903 |
| Melampsora Bigelowii Thüem.<br>(Salix spp.) | †Caeoma sp.<br>(Larix spp.) | Arthur<br>1904 |
| Melampsoridium Betulae (Schum.) Arth.<br>(Betula lutea) | ††Peridermium Laricis Arth. & Kern<br>(Larix sp.) | *Plowright<br>1890 |
| Gymnosporangium Juniperi-virginianae Schw.<br>(Juniperus Virginiana) | Roestelia pyrata Thaxt.<br>(Malus spp. & Pyrus communis) | Thaxter<br>1886 |
| Gymnosporangium globosum Farl.<br>(Juniperus Virginiana) | Roestelia globosa Farl.<br>(Crataegus spp.) | Thaxter<br>1887 |
| Uromyces acuminatus Arth.<br>(Spartina cynosuroides) | †Aecidium sp. (2)<br>(Steironema ciliatum) | Arthur<br>1905 |

1. Proven by cultures, not yet collected.
2. Connection not yet verified with Indiana material.

| | | |
|---|---|---|
| Uromyces Solidagini-Caricis Arth.<br>(Carex spp.) | Aecidium sp.<br>(Solidago spp.) | Arthur<br>1903 |
| Uromyces Silphii (Syd.) Arth.<br>(Juncus tenuis) | Aecidium Silphii (Bur.) Syd.<br>(Silphium perfoliatum) | Arthur<br>1906 |
| Puccinia Sorghi Schw.<br>(Zea Mays) | Aecidium oxalidis Thuem.<br>(Oxalis cymosa) | Arthur<br>1904 |
| Puccinia pustulata (Curt.) Arth.<br>(Andropogon spp.) | Aecidium pustulatum Curt.<br>(Comandra umbellata) | Arthur<br>1903 |
| Puccinia Andropogi Schw.<br>(Andropogon spp.) | Aecidium Pentstemonis Schw.<br>(Pentstemon hirsutus) | Arthur<br>1899 |
| Puccinia Pammelii (Trel.) Arth.<br>(Panicum virgatum) | Aecidium Pammelii Trel.<br>(Euphorbia corollata) | Stuart<br>1901 |
| Puccinia Majanthae (Schum.) A. & H.<br>(Phalaris arundinacea) | †Aecidium Majanthae Schum.<br>(Salomonia & Vagnera) | *Sopitt<br>1889 |
| Puccinia verbenicola (K. & S.) Arth.<br>(Sporobolus longifolius) | Aecidium verbenicola K. & S<br>(Verbena stricta) | Arthur<br>1899 |
| Puccinia Rhamni (Pers.) Wettst.<br>(Avena sp. & Colamogrostis sp.) | Aecidium Rhamni Pers.<br>(Rhamnus lanceolata) | **DeBary<br>1865 |
| Puccinia Windsoriae Schw.<br>(Tricuspis sealerioidea) | Aecidium Pteleae B. & C.<br>(Ptelea trifoliata) | Arthur<br>1899 |

| | | |
|---|---|---|
| Puccinia Eatoniae Arth.<br>(Eatonia Pennsylvanica) | Aecidium Rannuculi Schw.<br>(Rannuculus abortivus) | Arthur<br>1903 |
| Puccinia epiphylla (L.) Wettst.<br>(Poa pratensis) | Aecidium Tussilaginis Pers. (3)<br>(Petasites frigida) | *Nielson<br>1876 |
| Puccinia Impatientis Arth.<br>(Elymus Virginicus) | Aecidium Impatientis Schw.<br>(Impatiens spp.) | Arthur<br>1902 |
| Puccinia poculiformis (Jacq) Wettst.<br>(Various grasses and grains) | Aecidium Berberidis Pers.<br>(Berberis vulgaris) | **DeBary<br>1864 |
| Puccinia Rubigo-vera (DC.) Wint.<br>(Various grains) | ††Aecidium asperifolii Pers.<br>(Anchusa arvensis) | *DeBary<br>1865 |
| Puccinia canaliculata (Schw.) Lagerh.<br>(Cyperus strigosus) | Aecidium Compositarum Xanthii Burr.<br>(Xanthium Canadense) | Arthur<br>1905 |
| Puccinia Eleocharidis Arth.<br>(Eleocharis palustris) | Aecidium Compositarum Eupatorii DeT.<br>(Eupatorium perfoliatum) | Arthur<br>1905 |
| Puccinia obtecta Pk.<br>(Scirpus sp.) | †Aecidium Compositarum Bidentis Burr.<br>(Bidens frondosa) | Arthur<br>1907 |
| Puccinia angustata Pk.<br>(Eriophorum spp. & Scirpus spp.) | Aecidium Lycopi Ger.<br>(Lycopus Americanus) | Arthur<br>1899 |

3. Nielson, in his cultures, employed Tussilago Farfara L. which is the host of this not uncommon aecium in Europe. So far as is known to the writer, this aecium has not been collected on this host in North America, but the one on Petasites frigida, which seemingly is morphologically identical, has been collected by Piper in Alaska, and by Macoun on St. George's I., Behring Sea.

| | | |
|---|---|---|
| Puccinia albiperidia Arth.<br>(Carex spp.) | Aecidium albiperidium Arth.<br>(Ribes spp.) | Arthur<br>1901 |
| Puccinia Caricis-asteris Arth.<br>(Carex spp.) | Aecidium asterum Schw.<br>(Aster spp.) | Arthur<br>1901 |
| Puccinia Caricis-Erigonitis Arth.<br>(Carex spp.) | Aecidium erigeronatum Schw.<br>(Erigeron spp.) | Arthur<br>1901 |
| Puccinia Caricis-Solidaginis Arth.<br>(Carex spp.) | Aecidium Solidaginis Schw.<br>(Solidago spp.) | Arthur<br>1902 |
| Puccinia Sambuci (Schw.) Arth.<br>(Carex spp.) | Aecidium Sambuci Schw.<br>(Sambucus canadensis) | Arthur<br>1901 |
| Puccinia Peckii (DeT.) Kellerm.<br>(Carex spp.) | Aecidium Peckii DeToni<br>(Onagra biennis) | Kellerman<br>1902 |
| Puccinia Urticae (Schum.) Lagh.<br>(Carex spp.) | Aecidium Urticae Schum.<br>(Urtica gracilis) | **Magnus<br>1872 |
| Puccinia Polygoni-amphibii Pers.<br>(Polygonum spp.) | Aecidium sanguinolentum Lindr.<br>(Geranium maculatum) | **Tranzschel<br>1903 |

SUMMARY.

| | 1864 | 1865 | 1872 | 1876 | 1886 | 1887 | 1889 | 1890 | 1899 | 1901 | 1902 | 1903 | 1904 | 1905 | 1906 | 1907 | Total for Each Worker. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DeBary | 1 | 2 | | | | | | | | | | | | | | | 3 |
| Magnus | | | 1 | | | | | | | | | | | | | | 1 |
| Nielson | | | | 1 | | | | | | | | | | | | | 1 |
| Thaxter | | | | | 1 | 1 | | | | | | | | | | | 2 |
| Plowright | | | | | | | | 1 | | | | | | | | | 1 |
| Sopitt | | | | | | | 1 | | | | | | | | | | 1 |
| Arthur | | | | | | | | | 4 | 4 | 2 | 4 | 2 | 3 | 1 | 1 | 21 |
| Stuart | | | | | | | | | | 1 | | | | | | | 1 |
| Kellerman | | | | | | | | | | | 1 | | | | | | 1 |
| Transschel | | | | | | | | | | | | 1 | | | | | 1 |
| Clinton | | | | | | | | | | | | | | | 1 | | 1 |
| Total for each year | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 5 | 3 | 5 | 2 | 3 | 2 | 1 | |

## TELIAL FORMS WHOSE AECIAL CONNECTIONS ARE UNKNOWN.

| | |
|---|---|
| Coleosporium Ipomoeae (Schw.) Burr. | on Ipomoea pandurata. |
| Coleosporium Vernoniae B. & C. | on Vernonia spp. |
| Pucciniastrum Agrimoniae (DC.) Diet. | on Agrimonia spp. |
| Pucciniastrum Hydrangeae (B. & C.) Arth. | on Hydrangea arborescens. |
| Uromyces graminicola Burr. | on Panicum virgatum. |
| Uromyces Rynchosporae Ellis | on Rynchospora alba. |
| Uromyces perigynius Halst. | on Carex virescens. |
| Puccinia Ellisiana Thuem. | on Andropogen scoparius. |
| Puccinia emaculata Schw. | on Panicum capillare. |
| Puccinia Muhlenbergiae A. & H. | on Muhlenbergia spp. |
| Puccinia vexans Farl. | on Atheropogon curtipendulus. |
| Puccinia Melicae Syd. | on Melica diffusa. |
| Puccinia apocrypta E. & T. | on Hystrix Hystrix. |
| Puccinia Dulichii Syd. | on Dulichium arundinaceum. |
| Puccinia vulpinoidis D. & H. | on Carex vulpinoidea. |
| Puccinia ludibunda E. & E. | on Carex sparganioides. |

## AECIAL FORMS WHOSE TELIAL CONNECTIONS ARE UNKNOWN.

| | |
|---|---|
| Aecidium sp. | on Syndesmon thalictroides (Rue Anemone). |
| Aecidium sp. | on Anemone Virginiana (Tall Anemone). |
| Aecidium Dicentrae Trel. | on Bicuculla cucullaria (Dutchman's Breeches). |
| Aecidium sp. | on Euphorbia commutata (Tinted Spurge). |
| Aecidium Napacae Arth. | on Napaea dioica (Glade Mallow). |
| Aecidium hydnoideum B. & C. | on Dirca palustris (Leather-wood). |
| Aecidium Polemonii Pk. | on Polemonium reptans (Greek Valerian). |
| Aecidium Physalidis Pk. | on Physalis heterophylla (Ground-cherry). |
| Aecidium Compositarum Ambrosiae Burr. | on Ambrosia trifida (Great Ragweed). |

# Some Anomalies in the Female Gametophyte of Pinus.

By D. M. Mottier.

The object of this note is to call attention to some peculiarities in the number and arrangement of archegonia and to certain other anomalies similar in character to those reported for the same and other species of *Pinus*. In her excellent and elaborate paper on the life history, etc., of *Pinus*, Miss Ferguson has directed attention to a number (9) of archegonia arranged along the top and sides of the endosperm of *Pinus montana uncinata*, together with other peculiarities regarding the number, origin and position in other species (Proc. Washington Acad. Sci., 6: 1-202, 1904).

In the work of a class of advanced students studying the gametophyte and embryogeny of *Pinus*, a number of peculiarities mentioned in the following have been found to be of rather frequent occurrence. In *Pinus austriaca* (a form of *P. laricio* frequently cultivated), several instances were observed in which a group of archegonia occurred at the chalazal end of the endosperm in addition to the group normally at the top or micropylar end. In addition to this a few cases were found in which a third group of archegonia was present at one side. Among those ovules in which a group of archegonia was present at either end, one case is especially of note in which a total of eleven archegonia was present, two near the micropylar and nine at the chalazal end of the gametophyte. The two near the micropylar end were not directly at the top but at opposite sides of that end. The nine at the chalazal end were arranged in groups of three each. One group of three was at the end, the others being more deeply seated. The second three were just beyond the first and a little to the right, while the third group was beyond the second, though somewhat to the left. In the majority of cases here under consideration the collections were made before the archegonia were mature, the ventral canal cells not having been formed. Four of the archegonia near the chalazal end had fused in pairs, a cytoplasmic union having taken place at the contiguous sides. This was made possible by the absorption of several sheath, or jacket, cells separating the archegonia. The three

groups were separated from each other by a layer of tissue from one to three cells in thickness. The central cells of two of the archegonia of the end group had fused at the outer ends only, although the sheath cells had entirely disappeared along the contiguous sides, leaving only a delicate line between the plasma membranes of the slightly shrunken cells. No nuclear fusions had taken place. Near each of these several archegonia one or more sheath cells had begun to bud out apparently to form archegonia as figured by Miss Ferguson (l.c., Fig. 265). In several preparations showing one or more of the anomalies herein mentioned, the enlargement of one or more of the sheath cells was of frequent occurrence. These enlarging cells possessed each a large nucleus and a dense cytoplasm, showing that they were being well nourished. In one ovule presenting a group of archegonia at each end of the endosperm, two large cells very poor in cytoplasm and about one-third the size of the normal archegonia lay between a normal archegonium and the end of the gametophyte at the chalazal extremity. From all appearances they had developed from sheath cells. They were not surrounded by jacket cells, hence their sparse cytoplasm.

Of this class of anomaly, namely, the presence of archegonia at opposite ends of the gametophyte, a few cases were observed in which there were *three* separate groups, one at each end and one at one side nearly midway between the extremities. In another instance the nucleus of the central cells had divided, the two daughter nuclei, which were well formed, lying in contact side by side. In this ovule all archegonia were immature; the ventral canal cells were not formed, and there was no fusion of the central cells. The two nuclei must, therefore, have been formed by the division of the nucleus of the central cell.

A second class of anomaly was observed in a single instance. It was the presence of a pollen tube containing supernumerary nuclei. This tube had grown down prematurely along one side of the endosperm and had just begun to indent the latter. The tube contained the two male nuclei surrounded by the cytoplasm of the body cell, together with about twelve other nuclei varying greatly in size. The largest of these nuclei were about the size of the male nuclei or larger. Their structural details were sharp and distinct; each contained a very distinct, but delicate, nuclear net with two or more relatively small nucleoli. In the same ovule another pollen tube had traversed about two-fifths of its way down through the nucellar tissue. In this ovule archegonia were present at each end

of the gametophyte. These organs were not mature; the adult size had not been attained nor were the ventral canal cells cut off.

A third kind of peculiarity was observed in two instances in which three archegonia formed a group at the geometrical center of the endosperm. There was no sheath layer between adjacent sides of their central cells, but on all other sides they were surrounded by the typical jacket layer. In one archegonium of this group a ventral canal cell was in process of formation; the other two were younger. No canal or opening leading to the surface of the gametophyte could be made out, neither were any necks distinguishable in connection with these nor with many other cases mentioned in preceding paragraphs.

A fourth peculiarity to be recorded is the premature arrival of the end of the pollen tube at the archegonium. In two different cases out of the material used the pollen tube had reached an archegonium in which the ventral canal cell had not been formed, nor had these organs attained their adult size. In one of these instances the tube had actually penetrated the archegonium, but had not discharged its contents.

Of the number of ovules of *Pinus austriaca* in the collection from which these anomalies were found, about one-tenth showed archegonia in either end of the endosperm. A few anomalies similar to those were observed in *Pinus virginiana*. In this paper the author has endeavored only to record the facts as observed, reserving a discussion of their probable significance until more data will have been collected.

# Notes on the Native Seedless Persimmon.

(Preliminary Report.)

By William L. Woodburn.

In the vicinity of Indiana University there are a number of persimmon trees (*Diospyros Virginiana L.*) which during the year 1908 bore large numbers of seedless fruits. No single tree, however, was found which bore only seedless berries, while four or five bore fruits nearly all of which contained seeds. The size of the seedless berries, their distribution on the tree, the time of ripening and their flavor as compared with those containing seeds was noted. A preliminary study of the embryology of the persimmon was also made. Entire ovaries were fixed in chromic-acetic acid and embedded in paraffin for sectioning, and later as the ovaries hardened ovules were similarly prepared. As later developments showed, the material was taken from a part of the tree which bore for the most part seedless berries, so that the development of the embryo was not observed. This led to a careful observation of the distribution of the seedless persimmons on the tree.

As the persimmons matured it was noted that the lowest branches of the tree from which the material was collected bore mostly seedless fruits, while somewhat higher were a few with seeds, and in the top of the tree the majority contained seeds. The seedless fruits on this tree were somewhat smaller than those containing seeds. Another tree younger than the one just mentioned bore throughout the branches berries with and without seeds, although more seedless below than above. On this latter tree there were many seedless fruits quite as large as the others.

The following questions naturally arise: Why did one tree produce persimmons on the lowest branches which were practically all seedless, while the majority on the upper part produced seeds? Did fertilization depend on the transfer of pollen from some other tree bearing only staminate flowers, since all the flowers examined contained sterile stamens, but these were from a part of the tree which bore only seedless berries? Or were there perfect flowers present which produced all the fruits containing

seeds? Is pollination necessary for the production of a well-flavored and good-sized fruit? Is the absence of mature seeds due only to the lack of fertilization?

In regard to the first question observations have been made which answer it only in part. At the time of flowering, which occurs about the last of May and the first of June, ovules were prepared for sectioning from the lower part of the first tree already referred to. No difference was noted among the flowers, although those in the upper part of the tree were not examined. The flowers from the lower part so far as noted bore a well-developed pistil but sterile stamens. Sections through the ovaries of these flowers showed occasionally a well developed embryo sac, but in some instances complete embryo sacs were not observed. Quite often the antipodal cells, part of the egg apparatus or the polar nuclei seemed to be lacking. Difficulties in staining due to the presence of tannin in certain parts of the ovary may have been responsible for this apparent condition. The polar nuclei were found several times in an early state of fusion, but further than this there were no evidences of endosperm or embryonal development in any part of the embryo sac. The contents disorganize and small aborted seeds which often occur seemed to be due merely to a slight growth of the integuments. There were no evidences noted of either fertilization or pollination having taken place.

As regards the transfer of pollen from staminate trees, the latter are not known to exist within three or four miles of the tree in question. Whether bees carry pollen to this tree from a distance has not been observed. If the tree bears in part perfect flowers, which has not yet been determined, this may account for the production of seeds in some fruits and not in others. The flowers so far as examined contained only sterile stamens. If no perfect flowers are present the question as to the absence of seeds being due to the lack of fertilization becomes of some import.

While the seedless berries on this tree were nearly all small, on a second tree seedless fruits were found quite as large as the others, the flavor in each case being quite as good if not better, since the seedless fruits as a rule have less of the astringent quality so characteristic of most persimmons until thoroughly ripe and which often persists even then. Whether the large size of the persimmon with seeds is due to the influence of fertilization or to some native quality of the pistillate flower has not been discovered.

The Industrialist (No. 20, March, 1904, Kansas State Agricultural

College) figures and describes imperfect staminate flowers as borne on separate trees from those bearing perfect flowers. Among the perfect flowers on the same tree are sometimes borne imperfect pistillate flowers. From the perfect flowers and the imperfect pistillate flowers similar fruits ripened, but no occurrence of seedless fruits was noted. Purdue University Agricultural Experiment Station Bulletin No. 60 reports two or three varieties of seedless persimmons which had been sent into the station.

A second tree already referred to bore mainly seedlss fruits. In the upper part of the tree about 75% of the persimmons and in the lower part probably about 80% were seedless. Sometimes an entire picking (the fruits do not all ripen at the same time) would be seedless. These persimmons were excellently flavored, of a good size, and usually ripened earlier than those with seeds. The seedless, however, do not always ripen earlier, for some of the greenest on the tree, after ripening had begun, were found to be seedless. On the other hand, the earliest ripe were always seedless, one having been found on August 20th ripe and well flavored but rather small.

# Testing Seed Corn by Specific Gravity.

By Herbert A. Dunn.

The corn of our native Indians as found by the first settlers in this country was small in size and of an inferior quality. The white man realized the possibilities of this new corn and at once began to select and improve it. This has been a slow process, and more improvement has probably been made in the last generation than in all the years preceding. The average yield in the United States for the decade ending in 1875, according to J. W. T. Duvel, assistant in the seed laboratory, Bureau of Plant Industry, Washington, was 26.07 bushels per acre, and the yield for the decade ending in 1905 was 25.2 bushels; the largest yield in any one year was in 1906, 30.3 bushels per acre.

During the year 1907 practically one hundred million acres were planted in the United States, requiring sixteen and a half million bushels of seed. Observation has shown that 20% of this seed does not germinate, the chief reason for this being carelessness in selecting and caring for the seed corn.

The yield will depend on the vitality of the seed and on contingency of the weather and soil and cultivation. In years past corn has been planted with little thought of the type of grain and germinating power; often only a random test was made by the aid of a pocket knife. Experienced farmers say that this is a fairly good test but experiment stations rely on and advocate the germinating test. Both of these tests require much time.

Since the yield is largely dependent on the quality of the seed corn, a comparatively simple and efficient seed test is very desirable.

One day I accidentally dropped some kernels in a basin of water. I noticed that the majority of the kernels lay flat on the bottom, while some stood on end, and on examining the latter they were found to be shriveled on the germ end, or had blisters. This gave me an idea of using a specific gravity test, for it must be evident that by increasing the density of the solution the light kernels would rise to the top. The question arose: What should be added to the water that is both harmless and cheap? I

decided on glucose, one part of glucose to three of water, Sp. Gr. 1.21. In this mixture the light kernels came to the top. I thus had light and heavy kernels, and with these I experimented as follows:

*First Test.*—300 kernels were taken from every other row of an ear that tested "good" in the usual "seed box" germinating test: Lot 1, 300 kernels from the alternating rows were divided into two lots by the specific gravity test; lot 2 showed 258 heavy grains; lot 3, 42 light grains. (Lot 1 was not put in solution.) The vitality of these three lots was determined by testing in a box, under identical conditions.

GERMINATING RESULTS.

| | |
|---|---|
| Lot 1 (300 grains) | 86% germinated |
| Lot 2 (heavy kernels) | 89% germinated |
| Lot 3 (light kernels) | 69% germinated |

*Second Test.*—100 kernels were taken from an ear which showed a germinating test of 4 dead kernels and 1 weak out of 5 (the usual test number being 5). These kernels were separated by the specific gravity test and tested as before.

GERMINATING RESULTS.

| | |
|---|---|
| Of the 68 heavy kernels | 47% germinated |
| Of the 32 light kernels | 15½% germinated |

*Third Test.*—100 kernels were taken from two ears which showed "extra strong" in the germinating test. They were separated by the specific gravity test, which gave a high percentage of heavy kernels, and were tested under conditions similar to the above. (It will be noticed that the per cent of light kernels is quite small and that all germinated.)

GERMINATING RESULTS.

| | |
|---|---|
| Heavy kernels (91) | 100% germinated |
| Light kernels (9) | 100% germinated |

*Fourth Test.*—Two full rows were taken from 25 ears, in which all of the five test kernels had failed to germinate in the "box test." This gave a total of 2,116 kernels. The specific gravity test showed 592 heavy and 1,524 light; these were tested as mentioned above.

GERMINATING RESULTS.

| | |
|---|---|
| Of the 592 heavy kernels | 54% germinated |
| Of the 1,524 light kernels | 22% germinated |

*Field Test.*—Out of 125 bushels of selected seed corn, I reselected enough to plant a thirty-acre field—from which in turn seed for the following year was to be selected, and the germinating test for each ear had to be high. Out of this reselected seed a sufficient amount was put through the specific gravity test until there were enough light kernels to plant a row of 80 rods. The test corresponded with test No. 3, that is, 90 per cent. of the kernels were heavy; all germinated. These light seed were planted in a row alongside of one of heavy; the rows were "checked" and ran east and west, the light row being on the south. Now as our prevailing winds are from the southwest, one can readily see how there might thus be a slight difference: the row of heavy kernels might be fertilized by pollen from the light kernels rather than the reverse.

There was no perceptible difference in the appearance of these two rows, but when a count of stalks was made in August, the heavy row showed an excess of 129. When ripe, the ears from each row were husked and weighed, and there was found to be a difference of 20 pounds in favor of the heavy row—equivalent to nearly three bushels to the acre.

My conclusions from these experiments are as follows:

1. To test seed corn by the germinating test is time-consuming and expensive, and requires great care.

2. Choosing five kernels to represent 600 to 1,000 others from an ear does not prove to be an infallible method. (Test 4.)

3. To test by specific gravity is simple, rapid, and inexpensive.

4. The specific gravity test enables one to eliminate the weak kernels in a simple and practical manner.

5. The crucial test, the field experiment, shows that the light grains should be discarded.

# Notes on the Flora of Cass County.

By Robert Hessler.

(Abstract.)

This paper embraces a large collection of notes on the flora of Cass County, covering the years from 1894 to 1908, excepting the years 1898 and 1899, when the writer was away. The paper relates more particularly to plants which are not of general distribution in the State. The notes given under the different species of plants may be grouped as follows:

(a) Relating to plants, especially weeds, that have recently wandered in, particularly along the railways, either to maintain themselves and perhaps overrun the country, or, on the other hand, to lead a precarious existence for a year or two and then again disappear.

(b) Relating to plants that are apparently extinct or on the verge of extinction on account of the destruction of their natural habitats, as the cutting down of forests and bringing the ground into cultivation, or by simply thinning the trees to such an extent that shade-loving plants can no longer thrive. Moreover, with the thinning of the trees many weeds come in, also grasses, and they tend to crowd out the native plants. The draining of wet places, of swamps and bogs, has been going on actively in recent years and few such now remain in Cass County. There are fewer and fewer places where plants that were once common are now to be found, and it is only a matter of time until these, too, will lose their native flora. The old-time rail fence has furnished a home for many species, to which the wire fence gives no protection.

(c) Relating to plants that are undoubtedly native but which seem to come and go, being found in one locality for a year or a few years, and then disappear, to reappear in a distant locality and where they had not been seen before; that is, like people, they seem to be moving about—especially plants that are fond of moist soils; perhaps birds carry the seed.

(d) A lot of notes not fully worked up (for lack of time) relating to plants of interest on account of their medicinal or supposed medicinal value—either as "simples" or as real remedies used by the educated phy-

sician (a number are used by the patent and proprietary medicine men, with extravagant statements as to their value).

One can distinguish between: (1) Plants that have been brought in purposely, or which have come in accidentally, the ancient medical lore connected with them being continued; (2) Native plants to which old European lore has been transferred, often along with the old European names; (3) Native plants about which independent knowledge has been obtained (whether real or supposed is at times difficult to determine), that is, not based on old statements in European literature.

The writer wishes these notes to be considered as a contribution to the knowledge of the flora of Indiana, and as showing more particularly how old plants are disappearing and new ones coming in. The writer says:

"This is a subject that should be of interest to botanists everywhere, and especially to the amateur. To me it is certainly a great pleasure to get out occasionally and note the changes that are constantly going on—changes so gradual that few are aware of them at all. I have repeatedly seen a new plant, generally a weed, come in and within a few years become a feature of the landscape. We need only think of the White Sweet Clover, a rank plant, that in places, especially along country roadsides, has crowded out all other plants.

"In this connection I might refer to my paper on the Adventitious Plants of Fayette County, presented before this Academy in 1893, and on the Flora of Lakes Cicott and Maxinkuckee, in 1896; also to the many papers given before the Academy by men from all over the State. Such lists are useful for the purpose of making comparative studies.

"I hope some one will gather up all the available data and publish them for the benefit especially of high school students, many of whom can be led to interest themselves in this subject. It is not a difficult matter to become acquainted with one's local flora, and to detect new arrivals. Such information may also be of value to the farmer.

"In going over my notes, I realize the importance of making memoranda of observations at the time. There are some facts about the flora of Cass County that I thought I would always remember, but I now find that I am not sure about the presence or absence of certain plants, say twelve years ago, and in my list I have several times been compelled to refer to this. One may be reasonably sure about a fact, but unless one has notes, made at the time, there may always be some doubt.

"I would like to add another word, and that is, the value of the training derived in studying botany, in identifying plants, and in noting the changes going on. This training is of great value to the man who desires to become a physician. To differentiate many species (and we need only think of the Asters and Golden-rods) requires patience and close study—and the experience is of value to the physician, by helping him to make distinctions between diseases and states of ill health that appear as one to the careless observer.

"I may add that a number of photographs have been taken of native plants in localities or habitats that are now undergoing destruction, especially of swamps and bogs and wet woods. A few years more and the localities will be wholly altered, and with this alteration the flora will have disappeared; it will exist only in herbaria, in photographs, and in memory."

# A New Anthracnose Attacking Certain Cereals and Grasses.

By A. D. Selby and Thos. F. Manns.

(Abstract.)

This paper states briefly the results of culture investigations of a fungus described as *Colletotrichum cereale*, n. sp. This has been found to be present over the State of Ohio, attacking the spikes, culms and sheaths of rye, the culms and sheaths of wheat, oats, chess, orchard-grass, timothy, red-top and blue-grass. Upon the cereals the attack is timed to the approaching maturity of the plant and produces marked shriveling of the grain. The behavior of the fungus on different media is stated, and different illustrations are included. It will be published in bulletin No. 203 of the Ohio Agricultural Experiment Station.

# The Dissemination of Disease by Means of the Seed of the Host Plant.

By M. F. Barrus.

(Abstract from thesis presented in June, 1908, at Wabash Collegee, Crawfordsville, Indiana, for Eastman Biological Prize.)

It has been known for a long time that diseases can be spread by means of the seed of the host plant. As early as 1730 Jethro Tull recommended a change of seed to avoid smut. Since then the list of such diseases has steadily increased until now there is a large number of them.

A knowledge of the method by which infection of the seed takes place and of the subsequent growth of the parasite is of value, since it will reveal a vulnerable point of attack, if there be any, in seeking means of controlling the disease. It is the purpose of this paper to indicate briefly those diseases of cultivated plants which are disseminated by means of the seed of the host plant and to point out the method by which the seed becomes infected.

These diseases can be divided into two classes, those which infest the seed internally, i. e., the organism entering the maturing seed and existing within in a dormant condition until the germination of the seed; and those which infest the seed externally, i. e. the organism or its spores becoming attached to the surface of the seed and entering the host plant at the time it germinates. The diseases belonging to the former class are the Anthracnose of Beans, the Blight of Peas, the Loose Smut of Wheat and Barley, and possibly a few of the Rusts. Under the latter class may be included most of the Smuts, the Wilt of Flax, and probably some of the Rusts and a few Bacterial diseases.

## Bean Anthracnose.

*Colletotrichum lindemuthianum* (Br. & Cav.) on *Phaseolus vulgaris.*

The fungus causing this disease survives the winter in the seed of the host plant. If the affected pods are allowed to ripen on the vines, the mycelium of the fungus penetrates further and further, eventually entering the seeds, usually causing them to become spotted (Figs. 1 and 2). Here

the mycelium remains in a more or less dormant state until conditions are favorable for the germination of the bean seed, when it renews its activity.

An examination of a diseased seed will reveal an abundance of mycelium in the infected portions. By carefully treating the seed with hot water or formalin to rid them of surface fungi and placing them in a sterile moist chamber, one is able to obtain spores in great profusion on the seed before it has germinated and later on the cotyledons, stems and leaves of the seedling in the sunken and discolored cankers caused by the fungus. Dr. Halstead reports that he has found spores of the Anthracnose on the dry beans, especially in the cavity between the cotyledons.[1]

In the germinating plant, no doubt the plumule is often infected by contact with the diseased portions of the cotyledons. (Fig. 3.) Spores, however, are produced upon the cotyledons after the bean has expanded its true leaves and when released by the dissolution of the mucilaginous matrix they are washed to the ground or on the stems below. The stems become infected from these spores and cankers are formed at the infected places. Often these cankers encircle the stem and thus cut off the supply for the leaves above. Sixty-one German Wax Beans apparently healthy were planted in the greenhouse. When well up five were observed which had infected cotyledons, the others appearing healthy. Seventeen days after planting thirty-one of the plants were affected by the disease at the base of their stems, showing, doubtless, that spores from the cotyledons of the five plants had infected the stems of the others. (Fig. 4.)

When the plants are moist the spores of the fungus are in a condition to be easily disseminated, so that working among the plants at this time or otherwise disturbing them aids in the dissemination of the fungus if any diseased plants are present. Even the wind aids dissemination by scattering contaminated drops of water to healthy plants, or by blowing the plants against each other. In this way the disease spreads to the leaves, stems and pods of the plant during the growing season.

The selection of seed from unaffected pods seems at present to be the most satisfactory method to pursue in controlling the disease. The pods should be selected in the field and only such as are perfectly free from all evidence of disease should be selected. Apparently healthy beans within an infected pod may harbor the mycelium of the fungus without showing any evidence of it. Enough seed can be selected in this way to plant small patches. Those who grow large areas should select enough beans to plant

1. Halstead, B. D., The Anthracnose of the Bean. A Remedy Suggested. Ann. Rept. N. J. Agr. Exp. Sta. 1891, p. 284.

half an acre and use the beans from this seed-patch for subsequent plantings. By careful selection after this manner each year the disease can be controlled to a profitable extent.

### Sunscald of Pea.

*Ascochyta pisi* Libert. on *Pisum sativum.*

During the summer of 1907, my attention was called to this disease affecting the garden pea. As observed at this time, the leaves, stems and pods were badly spotted. (Fig. 5.) The spots on the pods were not confined to the surface alone, but in many cases extended entirely through the pod, as was evident from the fact that spots were found exactly opposite those on the other side and the seed between the affected portions was discolored or distinctly spotted by the disease. I gathered a number of the diseased pods of both early and late varieties and planted twenty-three seeds of each variety in the greenhouse during the winter following. Several seeds of the late variety were distinctly spotted. All of the early variety germinated and thirteen of the late variety. Those that did not germinate were found to be decayed. Soon after they came up, nearly all of the plants died. Usually the stem near the base withered and turned brown, resulting in the death of the young plant.

Five of the forty-six planted lived and produced pods. Even the lower leaves of these withered and dropped off, giving the plant a very straggling appearance. No spots such as were observed on the plants grown in the garden were to be seen, contrary to my expectation, but from the description of the disease given by others,[1] the trouble was undoubtedly due to Ascochyta.

Kruger, a German mycologist, found that if diseased seed was soaked in water from forty-eight to seventy-two hours, the mycelium of the fungus would completely encircle it, and grow out into the water, forming a white mass of radiating threads. Van Hook verified this statement and also found that if the diseased pea seed were placed in a germinator for a few days a heavy coat of white mold would be formed about them in which, if seed were removed to a covered dish with less moisture, numerous reddish-brown pycnidia would be formed.[2] These pycnidia were produced by the mycelium of the fungus which had lain dormant in the seed since its maturity. When the conditions were right for the germination of the seed the fungus renewed its growth. The mycelium grows within the stem con-

1. H. G. Howell, J. M. Van Hook.
2. Van Hook, J. M., Blighting of Field and Garden Peas. Ohio Bul. 173, 1906.

currently with the growth of the plant, causing lesions at its base and a withering of its lower leaves, and often its death before or soon after its appearance. Probably the embryo is affected by the fungus in most cases where the seeds do not germinate. The spores exuded from the lesions on the stems, leaves and pods are scattered by the wind and other agents, and infect healthy plants. If the spotted pods are left upon the vines until the seeds are mature the mycelium penetrates some of these seeds, which thus carry the fungus over the winter, making this an important means for the dissemination of the parasite.

Seed treatment has not been very effective in controlling this disease which, fortunately, with the exception of an occasional epidemic, is not very destructive. Rotation of crops is one method usually recommended.

### Loose Smut of Wheat.

*Ustilago tritici* (Per.) Jens. on *Triticum vulgare.*

It was formerly thought that the spores of this fungus became attached to the coat of the healthy seed and germinated at the time of the germination of the seed, infection threads from the promycele penetrating the first leaf-sheath, as is the case with stinking smut. But later investigations have made quite certain that the germinating spore infects the pistil of the healthy wheat at flowering time, the mycelium establishing itself within the ovary during its development and remaining dormant in the ripened seed until it had germinated, the mycelium then continuing its own development.[1] This fact explains why the results of seed treatment for this species have been negative to so large a degree.

During the latter part of June, 1907, I inoculated many wheat plants with the spores of U. tritici by dusting the young stigma with the spores. The stigma seemed to be most receptive when quite young. Records of inoculations were kept and heads gathered at varying intervals of time from date of inoculation. A pistil examined one day after inoculation showed that a number of spores adhered to the stigmas and that several had germinated. It was hoped that the point of infection would be observed and although the germ tubes of spores were seen directed toward the interior of the stigma, none were seen entering or within. Spores were also germinating on the surface of the ovary and it may be that the point of entrance is through the ovary coat. Of those seeds which were

1. Brefeld and Falck, K., Flower Infection by Smuts. Untersuch. ges. Gebiet Mykol. 1905, No. 13. Abs. in Bot. Centbl. 101 (1906) No. 8: 212-213.

allowed to mature after being inoculated, thirty were planted in a box in the greenhouse on October 10th, 1907. On the 15th of May, 1908, the resulting wheat-plants had begun to head out. All the heads were more or less smutty. The majority of them were reduced to a mass of spores as is commonly observed in the field. In a few cases the ovary was the only part entirely destroyed, the outer portion being unaffected or only streaked with sori containing the spores. As the wheat plant develops the mycelium of the fungus grows upward probably much after the manner of the mycelium of the stinking smut. It enters the young head early in its formation and branches into numerous sporogenous hyphae, which completely destroy the pistil and other parts of the flower. These hyphae divide into a number of cells within each of which a chlamydospore is formed as in Oat Smut. The walls of the hyphae become gelatinous and later disappear, leaving the spores free. These dry on exposure to the air, forming a dusty mass so commonly observed at the flowering time of wheat. These spores are blown about by the wind and infect the ovaries of healthy heads, thus establishing the fungus for another year. (Fig. 6.)

### NAKED SMUT OF BARLEY.

*Ustilago nuda* (Jens.) Kell. and Sw. on *Hordeum vulgare.*

This Smut is similar in methods of attack and in field characteristics to the Loose Smut of wheat. The head is reduced to a mass of spores which are scattered at the flowering time of barley. These spores infect the ovaries of the healthy plants in which the mycelium of the fungus develops until the seed is ripe, remaining throughout the winter in a dormant condition and continuing its growth concurrently with the growth of wheat after seed is planted.

### THE STINKING SMUT OF WHEAT.

*Tilletia foetens* (B., & C.) Trelease and *T. Tritici* (Bjerk.) Wint. on *Triticum vulgare.*

*Tilletia foetens* has a spore with a perfectly smooth coat, while the epispore of *T. tritici* is much reticulated. Their method of infection and growth are similar.

The spores of these two smuts are scattered about at harvesting time or in some other way become attached to the healthy seed. When placed in a situation favorable for their germination they send out a short, thick promycelium and at its tip is borne a cluster of slender tapering sporidia

which conjugate in pairs. Infection threads are either produced by these sporidia capable of penetrating the host plant or, as is usually the case, secondary sickle-shaped sporidia are borne on short filaments and these sporidia produce infection threads. The formation of sporidia greatly increases the chances of the fungus to infect the host.

The infection of the wheat plant takes place soon after the germination of the grain and even before the first leaves are put forth. Hoffman believed that the infection threads can enter only the sheathing primary leaf or the collar between the root and stem while they are yet very young and delicate and concludes that anything which would hasten the growth of the young plant would tend to lessen the chances of infection.[1] Bolley believes that infection does not take place unless there is a large number of sporidia in close contact with the seedling during the infection period.[2] The mycelium after gaining entrance to the young plant pushes its way upward with the growth of the host, the older mycelium dying and its contents passing upward into the young advancing ends, and finally fruits in the ovaries by the production of chlamydospores from sporogenous hyphae that have developed abundantly in them. The Stinking Smut differs from the Loose Smut of Wheat in that the destruction is entirely confined to the ovary contents. The ovary coat is left intact, so that one would easily fail to recognize any infection unless he made particular observation or noticed the disagreeable odor characteristic of the fungus. The affected kernels are somewhat larger than healthy ones and this increase in size causes the florets to spread, making the head more open than a healthy one. When the kernels are cut open they are found to be filled with a mass of olive-brown spores of a greasy character.

### The Loose Smut of Oats.

*Ustilago avenae* (Pers.) Jens. and

### The Hidden Smut of Oats

*Ustilago levis* (Kell. & Sw.) Magnus on *Avena sativa.*

There are two distinctive species of oat smut called respectively the Loose and the Hidden Smut of Oats. Both are much alike in their methods of development and both succumb to the same method of treatment. *Ustilago avenae* is by far the commoner and is the one which causes the

1. Note from Kellerman and Swingle, Report on the Loose Smut of Cereals. 2d Ann. Rept. Kan. Exp. Sta. 1889. pp. 213-238.
2. Bolley, H. L., New Studies upon the Smuts of Wheat, Oats and Barley N. Dak. Bul. 27, 1897.

greatest damage of all grain smuts in the United States. The disease makes its appearance at the time of blossoming of the oat-plant, the whole head becoming a dusty olive-brown mass. The infected flowers are entirely destroyed by the disease and even the awns are affected. In the Hidden Smut the spore mass is more or less concealed by an outer membrane of the floral parts that remain intact from the disease. The dusty mass is made up of great numbers of spores which are blown about by the wind, some being caught in the open glumes of flowering oat-plants. Since after blossoming the glumes close tightly about the ovary, such spores are held imprisoned and remain so until the seed is in a condition to germinate. Then the imprisoned spores germinate after the manner of several smuts, producing a three or four-septate promycelium, which usually bears oval or elliptical sporidia at the apex or laterally at the septa. Infection threads are usually produced by these sporidia, but the promycelial threads may also produce them. These infection threads gain entrance to the host by piercing the delicate young cells of the first leaf-sheath before the leaf has appeared. Plants are free from infection after the growing leaves have pushed themselves as much as one c. m. through the leaf-sheath. Brefield found by experimentation that oats germinated up to 15° C. gave 3 per cent. smutted heads, but when grown at a higher temperature give 1 to 2 per cent. smutted heads or more.[1] This bears out ordinary experience that late sown oats while more liable to rust are freer from smut. This immunity is probably due to the short period when the plant is open to infection as a result of the rapid germination and growth of the seed in the more favorable condition of temperature.

In from thirty-six to forty-eight hours after infection considerable mycelium will be developed which penetrates the first and second leaves and gains entrance to the stalk or culm. It grows upward and invades the young head in quite the same manner as in case of other smuts. In place of a healthy head, a dusty mass of spores appears, which are scattered to healthy heads by the wind.

1. Brefield, O., Recent Investigations of Smut Fungi and Smut Diseases. Trans by Erwin F. Smith. Jour. Mycol. VI, pp. 1-8; 59-71; 153-164. 1890-91.

### Covered Smut of Barley.

On *Hordeum vulgare.*

*Ustilago hordei* (Pers.) Kell. & Sw.

This smut differs from *Ustilago nuda* in its method of infection and in its appearance in the field. The floral parts are not as completely destroyed and these serve to confine the spore mass and thus keep the spores from escaping until threshing time. Although they have a smooth epispore they cling to the seed and germinate with it, producing sporidia in abundance, laterally and terminally, upon a two to three-septate and elongated promycelium. These sporidia send out infection threads which penetrate the host in its early stage of growth. The swollen segments of isolated promycelium may also produce infection threads. The manner of growth in the host and the production of chlamydospores is similar to that of other loose smut.[1], [2]

### Other Smuts Carried Over by the Seed of Their Host Plants.

Grain Smut of Rice.

*Tilletia horrida* Tak. on *Oryza sativa.*

Head Smut of Sorghum.

*Spacelotheca Reitiana* (Kuhn) Clint. on *Sorghum vulgaris.*

Grain Smut of Sorghum.

*Spacelotheca sorghi* (LK.) Clint. on *Sorghum vulgaris.*

Grain Smut of Hungarian Grass.

*Ustilago crameri* Kom. on *Setaria italica.*

Leaf Smut of Timothy, Red-top, Blue-grass, and other Grasses.

*Ustilago striaeformis* (West.) Miessl.

Smut of Tall Oat Grass.

*Ustilago perennans* Rostr. on *Arrenatherum avenaceum.*

And smuts of many wild grasses.

### Flax Wilt.

*Fusarium lini* Bol. on *Linum usitatissimum* and *L. humila.*

The spores of this fungus become attached to the seed and germinate with it in the soil. These infect the roots of the young plant, often killing the seedling before it appears above ground. In case when plants live and

1. Clinton, G. P., Smuts of Illinois Agricultural Plants. Ill. Bul. 57, 1900.
2. Kellerman & Swingle, Reports on the Loose Smut of Cereals. 2d Ann. Rept. Kan. Exp. Sta., pp. 313-288: 1889.

are able to mature their seeds, they are frequently internally infected by the mycelium of the fungus and thus serve to carry the disease from season to season.[1, 2, 3]

## Rusts.

It is now believed by some pathologists that certain species of Puccinia are perpetuated by means of the seed of the host plant. Eriksson, after long investigation, came to believe that the fungus exists in the seed in a mycoplasmic form which can only with difficulty be detected from the protoplasm of the cells in the seed. As the plant grows, the mycoplasm spreads from cell to cell, finally appearing as mycelium in the intercellular spaces. He believes that the rust may be inherited from preceding crops by means of this mycoplasm.[4] It is generally believed that the facts do not warrant the acceptance of this theory. Bolley thinks that infection may take place from spores inside the seed itself. He found both uredo and teleutospores of Puccinia graminis borne in spore beds just below the bran layer of wheat and also found plenty of rust-mycelium within the seed.[5] Eriksson reports seed infection with Puccinia graminis and P. glumarum in wheat, oats, and barley, and P. dispersa on rye. Noack reports a case from Cooke of carnations being affected by rust which must have been caused by seed infection and he himself observed an incident of celery-rust that was likewise caused by infection from the seed.[6]

## Anthracnose of Tomato.

*Colletotrichum lycopercici* Ches. on *Lycopersicum esculentum*.[7]

## Bacteriosis, or Bacterial Blight of Beans.

*Bacterium phaseoli* Sm. on *Phaseolus vulgare*.[8]

This disease affects the stems, leaves, and pods (Fig. 7) of various field and garden beans, including limas. It spreads through the pods into the seeds, where the bacteria live through the winter, thus carrying the disease from season to season.

1. Bolley, H. L., Flax Wilt and Flax Sick Soils. N. D. Bul. 50, 1901.
2. Bolley, H. L., Flax and Flax Seed Selection. N. D. Bul. 55, 1903.
3. Bolley, H. L., Flax Culture. N. D. Bul. 71, 1906.
4. Eriksson, J., A General Review of the Principal Results of Swedish Research on Grain Rusts. Bot. Gaz. XXV; 26; 1898.
5. Bolley & Pritchard, Rust Problems, etc. N. D. Bul. 68: 1906.
6. Noack, Fritz, Die Verschlepping von Pflanzenkrankheiten durch Sämereien. Zeitsch. land. u. ver Hersen, 1893, No. 20, pp. 161-2. Trans. by Prof. H. H. Whetzel.
7. Harvey, F. L., Tomato Anthracnose. Me. State Coll. Ann. Rept. 1893. Part II, p. 152.
8. Whetzel, H. H., Some Diseases of Beans. Cor. Exp. Sta. Bul. 239, 1906.

### BLACK ROT OF CABBAGE.

*Baccillus campestre* (Pam.) Sm. on *Brassica oleracea* and *B. campestris.*

Infection takes place through the water pores of the leaves. The margins become affected and later the whole leaf withers and dies from thrombosis, i. e. by the plugging up of the xylem vessels by the bacilli. It has been shown while the bacilli will die when exposed from 8-10 days on a dry cover glass, they are able to live ten to thirteen months on the smooth surface of a cabbage seed, and that they often pass the winter in such a position.[1]

### STEWART'S SWEET CORN DISEASE.

*Bacterium stewartii.* Sm. on *Zea Mais.*

This is a thrombotic disease of sweet corn that is believed to be disseminated from year to year chiefly by means of bacteria clinging to the seed.[2]

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1. Harding, H. A.; Stewart, F. C.; Prucha, M. J. Vitality of the Cabbage Black Rot Germ on Cabbage Seed. N. Y. Exp. Sta. Bul. 251, 1904.
2. Stewart, F. C., A Bacterial Disease of Sweet Corn. N. Y. Exp. Sta. Bul. 139, 1897.

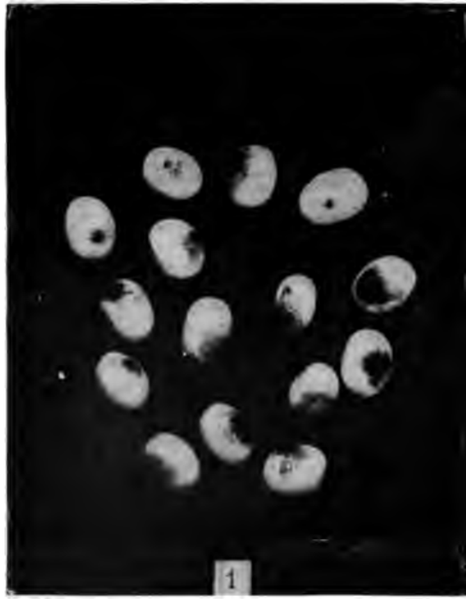

Fig. 1. Bean seed spotted with Anthracnose.

Fig. 3. Seedling bean plants showing Anthracnose spots on the cotyledons.

Fig. 4. The lower portion of stems of bean plants affected with Anthracnose, showing lesions near the base.

Fig. 5. Pea pods affected with *Ascochyta pisi.*

Fig. 2. Bean pod with canker cut away so as to show that the fungus had penetrated the seed.

Fig. 6. Heads of wheat affected with the Loose Smut.

Fig. 7. Bean pods spotted with Bacterial Blight.

# The Histological Difference Between Pinus Taeda and Pinus Palustris.

By Katherine Golden Bitting.

Though the structure of the wood of a tree will show considerable variation due to environment and conditions of growth, the variation will be manifest in the amount of wood formed, and the size of the cells. The characteristics which distinguish the particular wood remain constant, no matter what the external conditions may be, so that it is always possible to distinguish the wood of any species by the use of the microscope. It is not always possible to distinguish woods macroscopically, even by expert lumber men. This is particularly true of Coniferous woods, which are composed of only one form of element, the tracheides.

The close macroscopical resemblance of many Conifers, coupled with the variety of local names possessed by nearly every species, has caused much confusion in the lumber business. At present when a certain lumber is specified in a contract, many times the only guarantee that the contract will be properly filled will be the resemblance to the lumber named, along with information as to the locality from which it was shipped, the latter being the more reliable, if it be known to furnish pure groups.

Two of the hardwood Conifers which are confounded are Pinus taeda and Pinus palustris, or as they are more commonly known, Loblolly and Longleaf pine. In addition to these Loblolly has twenty-two other common names, and Longleaf twenty-seven, three of which are common to both.

Pinus taeda is of wide distribution, due to its adaptability to grow in different soils, consequently it shows considerable variation in its annual growth in both height and diameter. The best lumber is obtained from trees grown in mixed forests on well drained and fertile soil. These trees give the greatest growth in height, and a slower growth in diameter, both varying with the age of the tree. The zones of the spring and summer wood in the annual ring are nearly equal in extent, the spring wood shading gradually into the summer wood. In the gross, the zones are fairly distinct, but under the microscope it is difficult to define their proximate limit, as seen in the transverse and radial sections. The tracheides in

cross-section are approximately square or oblong, those in the summer wood being much thickened, leaving an irregular-shaped opening. The thickness varies from .00454 mm. in the spring wood to .0106 mm. in the summer wood. The length and width of the tracheides also vary, those in the spring wood being 6.444 mm. in length by .05606 mm. in diameter, those in the summer wood being 6,735 mm. by .03333 mm., being very slightly longer but decreased considerably in diameter, the decrease in width being accompanied by a greatly increased thickness. These figures are taken from the early spring and the late summer tracheides.

The resin ducts occur singly in both the spring and summer zones.

The medullary rays are somewhat obscure, one row of cells in width and 2 to 17 cells in height, except those which contain resin ducts, which widen and have a greater height.

In the longitudinal sections, the walls show striations which are fairly prominent, but have very little bowing apart of the walls.

Pinus palustris requires a drained soil in which to grow, its seed years occur at longer intervals, and thus it has a more limited distribution than P. taeda. It also has a lesser height and diameter, but has a finer grain, and greater weight. The zones of the spring and summer wood are distinct from each other, showing in well-marked lines, the summer wood appearing oily and compact as against the lighter line of the spring wood. The summer zone varies from about one-third to one-half of the annual ring. The two zones are so distinct that unless the thickness of the walls be noted carefully, the only difference between the limits of the summer wood is that the first growth shows an irregular line, whereas, the end of the zone for the year's growth forms a clean-cut ring.

The tracheides in transverse section are approximately square or oblong, with approximately round or elliptic openings left in the summer wood. Those in the spring wood average 4.4555 mm. in length by .04356 mm. in diameter, and the walls .00643 mm. in thickness. The summer tracheides average 4.8533 mm. in length by .0409 mm. in diameter, and the walls .01363 mm. in thickness. There is only a slight difference between the tracheides of the spring and summer zones in length and diameter, but the thickness of the walls is more than doubled.

The resin ducts occur singly, near to, and in, the summer wood.

The medullary rays are conspicuous, being one row of cells, rarely more, in width. They vary from 2 to 28 cells in height, except those containing resin ducts, which are much larger.

The walls of the tracheides bow apart to such an extent as to appear like a string of beads in the longitudinal sections.

In distinguishing the woods of the two trees the factors which are most prominent and also most readily obtained are in Pinus taeda, the junction of the spring and summer wood, in the year's zone, not distinct, the medullary rays somewhat obscure, and close together; in Pinus palustris spring and summer wood distinct from each other, the medullary rays conspicuous and farther apart, having a ratio of 4 to 11 to those in Pinus taeda. The other differences noted might be used in verification, but are not essential in the differentiation of the two woods.

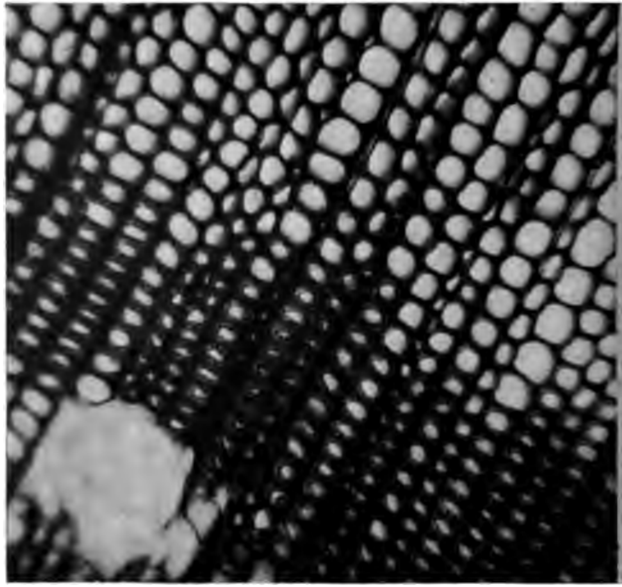

Fig. 1. Pinus taeda. Trans. sec. x 110.

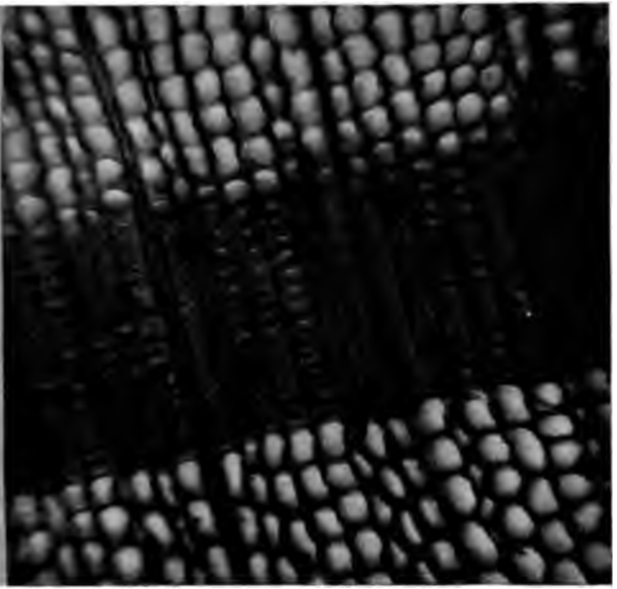

Fig. 4. Pinus palustris. Trans. sec. x 110.

Fig. 2. Pinus taeda. Trans. sec. x 395.

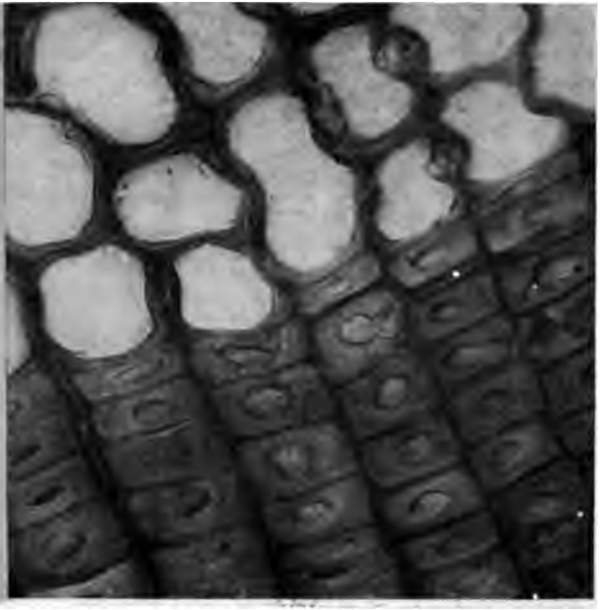

Fig. 5. Pinus palustris. Trans. sec. x 395.

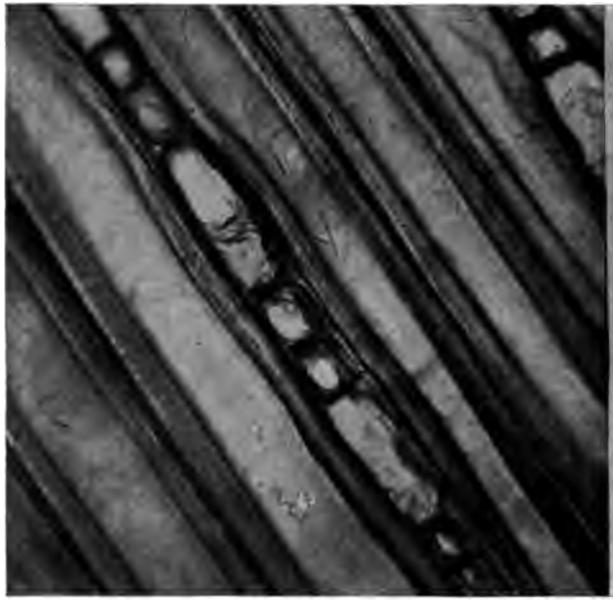

Fig. 3. Pinus taeda. Tang. sec. x 395.

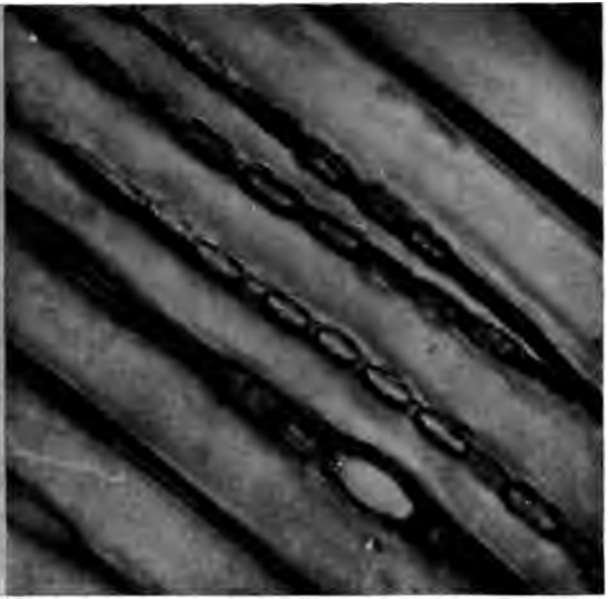

Fig. 6. Pinus palustris. Tang. sec. x 395.

# Report of Work in Corn Pollination.

By M. L. Fisher.

The work here reported was done during the season of 1908. A series of six studies was carried out in duplicate, as follows:

a. To determine period necessary for pollination in the field.

b. To determine the best condition of silks for pollination.

c. To determine time of day when pollination takes place most actively.

d. To determine the result of crossing with pollen from a variety of a different color or race.

e. To determine the vitality of pollen grains.

f. To determine the effectiveness of hand pollination.

All prospective ears were covered with paper bags before the silks appeared. Where hand pollination was performed, an umbrella was held over the shoot and to the windward while it was uncovered. Only the results obtained from "d" and "e" will be reported upon at this time. In all but "b," the silks used were three inches or more in length and in fresh condition.

The work under "d" was divided into four parts: d¹. The silks of Reid's Yellow Dent, a yellow variety, were pollenized with pollen from Boone County White, a white variety. Fairly well filled ears were obtained. The kernels had yellow bodies and almost uniformly whitish crowns. A few kernels were yellow throughout. The character of the kernel and ear, other than color, was uninfluenced.

d². The silks of Reid's Yellow Dent were pollenized with pollen from Stowell's Evergreen, a sweet corn, whitish in color and having wrinkled kernels when mature. Fairly well filled ears were obtained, but the character of the ear and kernel was unchanged. The only variation noticeable was a somewhat broader kernel, but such variation might occur without the effect of crossing.

d³. Reid's Yellow Dent was pollenized with pollen from a speckled variety. None of the kernels was speckled. A few had whitish crowns. Otherwise no change.

It should be said in this connection that the tassels from which the pollen was obtained were plucked in the afternoon and mailed in an envelope from Galveston, Ind., in the evening and used the next morning at Lafayette, Ind. The fertilization was not so complete as in other cases of hand pollination.

$d^4$. The silks of Boone County White were pollenized with pollen from Reid's Yellow Dent. Well filled ears were obtained. The kernels had uniformly yellowish bodies and white crowns. The kernels were shorter than the usual Boone County White kernel, but this may have been due to the extreme dry weather of the season. In all other ways the character of the ear was unchanged.

The work under "e" was divided into three parts.

$e^1$. Two five ear lots were pollenized with pollen 24 hours old. To obtain this pollen tassels were plucked in the afternoon and laid on paper in a room. The next morning the pollen was jarred out of the ripe anthers. The following morning this pollen was used to pollenize the selected ears. With pollen 24 hours old very well filled ears were obtained.

$e^2$. Two five ear lots were pollenized with pollen 48 hours old, obtained as in "$e^1$." The ears obtained from this pollination were not so well filled, there being many vacant places, showing a failure to fertilize.

$e^3$. Two five ear lots were pollenized with pollen 72 hours old, obtained as in "$e^1$." In this case practically no fertilization took place. The best ears had not more than 8 or 10 kernels on the cob, and the others only 3 or 4 kernels.

No conclusions are offered concerning these experiments. It is proposed to repeat the experiments in 1909, also to plant the corn obtained in $d^1$, $d^2$, $d^3$, and $d^4$, and note results.

# The Killing of Mustard and Other Noxious Weeds in the Grain Fields of South Dakota.

By E. W. Olive.

To the best of the writer's remembrance, mustard, though abundant enough, was not considered some years back as a serious pest in Indiana grain fields. But throughout the great grain fields of the Northwest the situation is different. The traveler sees on every hand, during the month of June, field after field of grain absolutely yellow with the blossoms of the common wild mustard. The fields sown to cereals are often enormous in extent; it is not an uncommon sight to see a quarter-section or even a section sown to one crop of wheat, barley, oats or flax. Only small areas here and there bear what we call "cultivated crops." Cultivation cannot therefore hold in check troublesome weeds as is done in the smaller farms of the older States. Hence the great abundance of the yellow pest through the older parts of the Dakotas is actually startling to a stranger from Indiana or Illinois.

One large land-owner in an effort to rid his ranch of mustard, two years ago spent a hundred dollars in pulling the weed. A year ago he doubled his expenditures in this work; but had to acknowledge finally that it seemed as though no matter how careful and clean his methods of farming, for years to come he might have to continually increase his appropriation in geometrical ratio before he could ultimately hope to conquer the pest.

It may be of some interest to the members of the Academy to hear a brief account of some of the experiments conducted by the writer during the past summer in trying to eradicate mustard and other weeds in grain fields. Similar experiments had already been performed in North Dakota, Canada, Minnesota, Wisconsin, and other western States, so that the results obtained in South Dakota are in the main corroboratory.

The method, in brief, is this: The grain field is carefully gone over with a traction spraying machine, and sprayed thoroughly with a strong solution (about 20 per cent.) of iron sulphate (or copperas). The machine used in our experiments covered a swath about twenty-five feet wide and threw a very fine and powerful spray, under a pressure of from 80

to 100 pounds, directly down on to the young mustard and grain. Twenty-five acres were easily covered in five hours, so that under favorable conditions, 40 to 50 acres could be readily sprayed in one day. The spraying is best done when the grain and weeds are from 6 to 10 inches high, or just before the mustard plants begin to bloom.

Further, it is highly important that the spraying be done during favorable weather. The great importance of this will be seen when we come to consider the physiological side of the problem. The best time for the most successful work is just after the dew is off, on a bright, sunshiny day. A little Dakota wind also helps the process; but if a rain soon follows, the iron salt is washed off and the work comes to naught.

Now if we keep close watch of the plants sprayed we can readily follow the various steps of the destructive action of the salt. First, the sulphate dries on the leaves, leaving minute, whitish flakes on the surface. Next, we note after two or three hours, particularly in the case of such succulent plants as mustard, the appearance of many scattered, more or less translucent, *sunken* areas on the leaves. The leaves by this time appear to be somewhat wilted and the whole plant looks somewhat sick. Two or three hours later, close examination reveals the next step of the process, in the gradual blackening of the sunken areas. The microscope shows this to be due to the blackening of the cell contents of the shrunken cells. Further wilting and drying up of the leaves is soon followed, in 24 hours or so, by their complete death. In a few days to a week, most of the mustard leaves have fallen off, or remain as dry, withered remnants on the dead stems. Occasionally a leaf may make a weak revival; or a plant here and there may make a futile effort at flowering and seed production. But if the work is thoroughly done, but few weeds survive. I have seen mustard so thick as to approximate 100 plants to the square foot, all totally destroyed by effective spraying.

After following the above description of the various steps in the appearance of a sprayed leaf the interpretation of the physiological action of the sulphate seems clear. First, the salt drying in minute flakes on the surface of the leaf, undoubtedly acts as a strong plasmolyzing agent to draw the water out of the cells with which it is in immediate contact. Thus results the scattered, translucent, sunken areas, merely from plasmolysis of those regions by the overlying salt. This plasmolysis is particularly striking in the case of the ragweed, which responds to the action of the sulphate even more quickly than does mustard or other weeds in-

vestigated. A sprayed solution of common salt apparently acts likewise, first as a strongly plasmolyzing agent, but its action is even quicker than that of the sulphate, plasmolysis resulting even in from 10 to 15 minutes after the application of the spray. Wilting of the entire leaf soon follows, due to general withdrawal of water, to be succeeded in a few hours by the blackening of the protoplasm of the plasmolyzed cells. This blackening is quite probably due to the formation of sulphides by the union of the absorbed iron sulphate with the protoplasm. After the use of common salt, on the other hand, the plasmolyzed spots turn reddish brown; possibly chlorides of some sort, formed in the killed protoplasm, may be responsible for the color in this instance.

It seems clear, then, that the action of the salts in killing the weeds in these experiments is due primarily to their osmotic properties rather than to their toxic properties; although it may well be that chemical action also may enter in after the first steps in the process and may contribute toward the death of the plants.

One of the most interesting sides of the whole problem of spraying for weed destruction is the fact that while mustard, ragweed and most other common weeds are for the most part totally destroyed, the wheat, oats, flax, etc., are themselves but little injured. This sounds almost unbelievable—much like a patent medicine advertisement, in fact. But it is nevertheless true that the grain soon recovers from the effects of the treatment; and further, Prof. Bolley's statement seems true, that the sprayed field often yields as much as one-third more grain than the unsprayed.

A little examination of the sprayed field soon shows to what the grasses and grains owe their peculiar protection from serious injury. It is true that the tips of the young wheat leaves are blackened and killed; but it will be remembered that, when the plants are only six inches to a foot in height, the bases of most of the leaves are amply protected, enwrapped within the sheaths and lower leaves. Their freedom from injury arises, therefore, in the main from the method of indeterminate growth of grains and grasses. The waxy bloom which covers flax and many of the grains must also contribute considerable protection against injury, since the minute droplets of salt solution do not adhere readily to such a surface.

# THE MEYER MOLECULAR WEIGHT CALCULATION.

BY PERCY N. EVANS.

In the Victor Meyer method of determining molecular weights of vaporizable substances, as usually carried out, the material is converted into vapor at the bottom of the inner tube, the latter being kept at a constant temperature at least twenty degrees above the boiling point of the substance by keeping a suitable liquid in the outer jacket steadily boiling. When the vaporizing occurs, a quantity of air equal to the increase in volume is forced out from the upper part of the inner tube, through the lateral capillary, and collected over water in a eudiometer. It is assumed that this increase in total volume is the volume of the vapor; it would be more correct to deduct from this volume that of the original liquid, but failure to do so introduces an error of usually only one part in two hundred or more, and this may be considered negligible in view of unavoidable experimental inaccuracies.

In passing from the heated tube to the eudiometer the temperature of the air changes to that of the room, with a corresponding volume change; it is assumed that the vapor would undergo the same change in volume if reduced to the same temperature without condensation, since all gases and vapors show a nearly identical behavior with changes in temperature.

After passing into the eudiometer the air is saturated with water vapor. If the air in the inner tube at the beginning of the experiment is already saturated with moisture at room temperature no change in the degree of moistness results, and hence no change in volume due to this cause. It would therefore be incorrect in calculating the volume of air under standard conditions to deduct from the observed barometer reading the tension of aqueous vapor.

If, on the other hand, the air in the apparatus had been perfectly dry its volume is increased by its becoming saturated with moisture, and this should be allowed for by deducting the tension of aqueous vapor from the barometer reading.

If, lastly, the air in the apparatus at the beginning of the experiment

is neither saturated at room temperature nor perfectly dry, the change in the degree of moistness of the air on becoming saturated is what the air originally lacked of being saturated. The appropriate correction to introduce is that fraction of the tension of aqueous vapor for the room temperature which it lacked of saturation. Suppose the apparatus was originally filled with the air of the room, and that it was forty per cent. saturated at room temperature, sixty one-hundredths of the tension of aqueous vapor is the number to be subtracted from the observed barometer reading; the corrected reading is $B - \frac{100 - H}{100} w$, in which B is the barometer reading, H is the hygrometer reading in per cent., and w is the tension of aqueous vapor for the room temperature.

Nearly all works accessible to the author give such directions for the manipulation as involve the use of the air of the room in the inner tube, yet give for the calculation the correction B-w. The error introduced in this way would be greatest if the air were saturated with moisture, and would then amount at a room temperature of 20 deg. C. to 17 in approximately 760, or 1 in about 45, and this condition is closely approached in damp, warm weather. Omitting the correction altogether when the air used is nearly dry gives an equal error in the opposite direction, approximated in very cold weather.

A quite appreciable error, then, may be avoided and the calculation made more nearly correct theoretically by using the correction given above.

Of the works accessible to the author only H. Erdmann's Anorganische Chemie discusses the correction, directing that if the apparatus is filled with a dried gas the tension of aqueous vapor should be deducted; if with ordinary air, no correction should be made. All other works fail to consider the point, some deducting the tension, others not, without specifying the conditions.

# Relation of Fats to Moisture Content of Butter.

By O. F. Hunziker.

## IMPORTANCE OF MOISTURE CONTENT OF BUTTER.

The two principal constituents of butter are the fats and the water. The average sample of butter contains about 83.5 per cent fats and 13.5 per cent water; the remainder being made up of salt, curd, ash, sugar and acid.

The more water butter contains the lower is its per cent of fats, and the more butter can, therefore, be made from a given amount of fats. It did not take the alert butter maker, the creamery operator, the commercial man very long to appreciate the financial significance of this fact. In many instances the process of butter making was so modified as to increase the per cent of moisture to the extent where as high as 130 to 150 pounds of butter were made from 100 pounds of fats, while under normal conditions 100 pounds of fats yield between 116 to 122 pounds of butter. The result was that, up to a few years ago, the American markets were flooded with water-soaked butter.

Butter containing an excess of moisture is inferior in quality; its keeping quality is poor and its food value is low. So, in order to save the butter industry of the country from certain ruin and to protect the consumer from buying his drinking water in the form of water-soaked butter, a law was passed by act of Congress in 1902 and revised in 1904, classifying as adulterated butter all butter containing 16 per cent or more of water and placing a fine of 10 cents per pound of butter and a special tax of $50 per month on the manufacturer of adulterated butter.

When this law was put in force by the Internal Revenue Department it was found that, in certain localities and at certain seasons of the year butter makers experienced difficulties in keeping the moisture content below the legal maximum of 16 per cent, and the question naturally arose as to the practicability and justice of this standard and as to the advisability of modifying it.

## EXPERIMENTS CONCERNING THE FACTORS INFLUENCING THE MOISTURE CONTENT OF BUTTER.

Accurate data concerning the moisture content of butter were meager, and it seemed obvious that this question could be satisfactorily settled only by means of careful experiments. So, about two years ago, the Dairy Department at Purdue University started investigations concerning the variations of the moisture content of butter and the causes of these variations.

Analyses of butter of the Purdue Creamery and of about 30 creameries in the State showed that in spring and early summer there was a rapid and decided increase in the per cent of water in butter. Analyses of the composition of the butter fats in the same butter showed a decided increase in the per cent of volatile and soft fats (fats of a low melting point) and a corresponding decrease in the per cent of hard fats in spring and early summer.

These results suggested the possibility that the composition of the fats may, in a measure, control the per cent of moisture incorporated in butter. On the strength of this assumption the pure butter fat was extracted from various lots of butter, and by means of fractional crystallization at different temperatures the soft and the hard fats were separated from one another as completely as was possible with this method. The two classes of fats were then churned separately and under identical conditions as to the moisture present and temperature. The analyses of these churnings showed that the butter made from the soft fats contained about 50 per cent more water than the butter made from the hard fats.

The uniformity of the results of repeated experiments justified the conclusion that, other conditions being equal, the relation of soft to hard fats controlled the moisture content of butter.

## EXPERIMENTS CONCERNING THE CAUSES OF VARIATIONS IN THE PER CENT OF VOLATILE, SOFT AND HARD FATS.

The results just described naturally lead to the question, What are the causes underlying the variation in the proportion of soft and hard fats?

It is an established fact that certain feeds, when fed in excess, have a tendency to produce an excess of soft or hard fats in butter. Thus, for instance, cotton-seed meal, bran, corn, overripe fodders, etc., tend to

increase the per cent of hard fats, while linseed meal, gluten feeds, succulent pasture grasses, etc., are conducive to raising the per cent of soft fats. It is by no means established, however, that the feed is the only nor even the chief factor controlling the proportion of fats in milk. Thus at the time when the soft fats increase in milk and butter produced in this section of the country most of the cows are fresh, and it is quite possible that the period of lactation exerts an important influence on the fats. It was, therefore, deemed expedient to investigate in how far the period of lactation does affect the fats in milk.

Three cows of the university herd were selected and fed during their respective periods of lactation on an uniform ration, evading such feeds as would tend to materially influence the hard or soft fats. The milk from each cow was separated, the cream ripened and churned separately, and the butter analyzed for volatile, soft and hard fats.

The generally accepted classification of milk fats is as follows:

$$\text{Glycerides of} \begin{cases} \text{a. volatile or soluble fatty acids.} \\ \text{b. insoluble fatty acids.} \end{cases}$$

The glycerides of the insoluble fatty acids are subdivided into hard and soft fats. The dairy literature, in dealing with the soft fats and their relation to the melting point of butter, gives consideration to the glycerides of the insoluble fatty acids alone. Inasmuch as the glycerides of the volatile or soluble fatty acids have a very low melting point as compared with that of insoluble fats, a comparatively slight change in the per cent of the volatile fatty acids must greatly influence the hardness or softness, as well as the melting point of butter. In determining the variations of the soft fats in butter it is necessary, therefore, to take into consideration the soluble as well as the insoluble fats.

The following charts show the results of analyses of butter made from the milk of the three cows under experiment:

TABLE I.—COWS 1 AND 2.

SHOWING THE EFFECT OF THE PERIOD OF LACTATION ON THE MILK FATS.

| TIME. | Reichert-Meissl Number. | Soluble Acids. | Insoluble Acids. | Iodine Number. | Melting Point. |
|---|---|---|---|---|---|
| 1st month | 32.41 | 7.39 | 87.26 | 29.96 | 36.2 |
| 2d month | 29.48 | 7.07 | 87.99 | 30.05 | 36.1 |
| 3d month | 29.95 | 7.08 | 87.90 | 29.98 | 36.4 |
| 4th month | 29.97 | 7.11 | 87.72 | 30.16 | 36.3 |
| 5th month | 29.56 | 7.00 | 87.72 | 31.88 | 35.9 |
| 6th month | 29.21 | 6.82 | 88.19 | 34.64 | 34.4 |
| 7th month | 28.06 | 6.45 | 88.4 | 36.15 | 35.0 |
| 8th month | 25.32 | 5.84 | 88.6 | 38.20 | 35.4 |
| 9th month | 25.45 | 6.01 | 88.5 | 36.4 | 35.5 |
| 10th month | 27.45 | 6.26 | 88.1 | 34.21 | 34.2 |

TABLE II.—COW 3.

SHOWING EFFECT OF THE PERIOD OF LACTATION ON THE MILK FATS.

| TIME. | Reichert-Meissl Number. | Soluble Acids. | Insoluble Acids. | Iodine Number. | Melting Point. |
|---|---|---|---|---|---|
| 1st month | 36.68 | 8.20 | 86.76 | 34.20 | 34.1 |
| 2d month | 35.75 | 8.09 | 86.74 | 34.25 | 34.2 |
| 3d month | 33.19 | 7.59 | 86.99 | 33.36 | 34.3 |
| 4th month | 33.80 | 7.56 | 86.95 | 33.83 | 34.0 |
| 5th month | 33.63 | 7.47 | 87.10 | 32.73 | 33.5 |
| 6th month | 33.57 | 7.55 | 86.94 | 31.02 | 33.7 |
| 7th month | 32.72 | 7.49 | 86.99 | 33.32 | 34.0 |
| 8th month | 31.63 | 7.25 | 87.41 | 33.59 | 33.92 |
| 9th month | 31.98 | 7.10 | 87.50 | 34.05 | 33.9 |
| 10th month | 32.03 | 7.12 | 87.46 | 33.22 | 33.8 |
| 11th month | 26.64 | 6.50 | 88.20 | 35.8 | 34.5 |
| 12th month | 30.48 | 6.86 | 87.69 | 32.05 | 34.3 |

These charts bring out the following facts:

1. The Reichert-Meissl number and the per cent of soluble fatty acids were highest at the beginning of the period of lactation; slight irregularities excepted, they decreased as the period of lactation advanced and were lowest towards the close of the period of lactation.

2. The insoluble fatty acids were lowest at the beginning, gradually increasing during and were highest at the end of the period of lactation.

3. The fact that the Reichert-Meissl Number, the soluble and the insoluble fatty acids bear a definite relation to one another shows clearly that the per cent of soluble and insoluble acids is affected by the period of lactation, and that the soluble acids decrease while the insoluble acids increase as the period of lactation advances.

4. The results concerning the iodine number are irregular, and, considering the relatively small number of data, do not warrant the drawing of definite conclusions as to the effect of the period of lactation on the per cent of olein in butter.

5. The relation of the per cent of soluble fats and olein to the melting point emphasizes that the olein is not the only factor controlling the melting point or softness of butter, but that the volatile or soluble fats play a part in the determination of the softness of butter.

# The Use of the Polariscope in Testing High Tension Insulators.

By C. Francis Harding.

It has long been known that glass internally strained, when placed in a polariscope in the path of polarized light produces upon the screen a chromatic effect, and that the colors thus produced rotate across the field as the analyzer of the polariscope is rotated. If, however, this peculiarity of glass has ever been put to practical use along engineering lines, such usage has not been common and its results have not been made accessible.

Without going deeply into the theory of the action of polarized light upon crystalline bodies or the similar phenomenon produced by the action of polarized light upon the imaginary planes into which the molecules are forced to arrange themselves within glass subjected to internal stresses, the writer has found the above mentioned color rotation in glass which is internally strained of the utmost value in testing glass insulators. Any ordinary piece of glass which shows no color rotation in the polariscope, when compressed in a vise or clamp and subjected again to the polarized light test exhibits streaks of purple and brown radiating from the points where the pressure is applied. The greater the pressure the brighter and more far-reaching the color effects seem to be, and when the analyzer is turned each color field seems to rotate about the point of application of the compressing force as a center. Similarly if a piece of ordinary glass showing no such effect be heated to a molten state and allowed to cool suddenly, the internal stresses due to irregular and unequal cooling will produce similar color rotation upon the screen.

With these facts at hand, several high tension glass insulators of different makes designed for a 33,000 volt transmission line were subjected to the polarized light test. Those of the No. 1 type, manufactured by one company, showed no color rotation in any portion, while those of type No. 2, designed and manufactured by another company for the same service, showed very marked effects. Some of the latter showed results more marked than others. In some the principal peculiarity noticeable

was the lack of uniform darkening and lighting of the entire field projected upon the screen as the analyzer was turned; while in others, especially in those that were whole, bright streaks of violet, purple and brown were seen, and found to rotate as the analyzer was rotated. In some cases these colored streaks were radial, and in still others they formed concentric rings about the knob of the insulator as a center. In order to prove more conclusively that these phenomena were caused by internal stresses, which were in turn produced by poor annealing, a portion of insulator No. 1, which showed no initial color rotation, was poorly annealed, and when tested again in the polariscope the color rotation effect was found to have been introduced. Conversely when a portion of insulator No. 2 was properly annealed the color rotation initially present was found to have disappeared.

The insulators which were first tested were those which had actually broken while in service upon the line, the parts of which were found on the ground near the poles where they were formerly installed. When later whole insulators of the same lot were tested it was found that in the latter the stresses were much more marked than in the broken parts. This fact caused the writer to suspect that some of the internal stresses produced by poor annealing were relieved by the breaking of the insulator, and to test this belief a whole insulator showing very marked color rotation was broken and the various parts placed in the polariscope for inspection. It was found that in spite of the fact that the same portion of the insulator which showed the most marked stresses was used when broken out, practically all the color rotation had been eliminated, although the stresses were still present to a less degree in the remainder of the insulator. In turn each quadrant of the umbrella of the insulator was broken out, and in each case the stresses were found to have been either reduced to a minimum or entirely eliminated. A further proof of the poor annealing was found in the fact that in insulators where the greatest stresses were present the umbrella shivered to bits when broken; while from insulators showing lesser stresses a whole quadrant could be broken out in a single piece.

Although it is very probable that insulators which are improperly annealed fail in service because of sudden temperature changes due to the weather and leakage of current over their surface, it seemed advisable to show, if possible, what effect, if any, the internal stresses had upon the mechanical strength of the insulator in order to determine whether the

possible unequal strain from the line wire could be considered a cause for breakage. Only four whole insulators were available for this test, two of which had marked internal stresses, while in the other two the stresses were almost negligible. The insulators were broken by placing them upon an iron pin as in service and by exerting a strain upon them in the direction of the line wire. One insulator which was poorly annealed broke at 960 pounds, while the others failed at 1,890, 1,675 and 2,220 pounds respectively, the latter being one which was also poorly annealed. While this test did not show very conclusively that the poorly annealed insulators were weak mechanically, it is believed that if the pull in the latter case, could have been in such a direction as to cause the insulator to break along strained internal planes as was probably the case in the first test, the latter insulator as well would have been found to have been weak mechanically. For conclusive evidence of this fact, however, a much larger number of tests should be available.

It will be seen from the foregoing, therefore, that a very practical use has been made of the phenomenon which has so long been only an interesting physical experiment. With the aid of the polariscope it is not only possible to determine some of the causes for the unsatisfactory service given by certain glass insulators, but it is also possible to make preliminary acceptance tests upon new insulators and to eliminate all of those which show signs of improper annealing and which for this reason would be undesirable for installation where they must be subjected, not only to severe electrical and mechanical strains, but also to vibration and sudden temperature changes. Although porcelain is rapidly supplanting glass for high tension insulators, it is expected that this method of test will be used in the future to advantage and that it will prove of equal, if not greater value, than it has in this particular instance.

# Some Contributions to the Chemistry of Mucoid.

By Clarence E. May.

In Physiological Chemistry, one meets with a proteid that has been receiving more or less attention for several years past. This proteid is classed among the glyco-albumins and occurs especially in ligaments and tendons. Heretofore, the main problem connected with the chemistry of this substance or group of very closely related substances, as the case may be, has been the quantitative separation of the mucoid from mixtures of albumin such as blood and egg albumin, and mucoid. The usual method of separation has been to boil the neutral solution of true albumin and mucoid, thereby coagulating the blood or egg albumin and leaving the mucoid in the filtrate. By acidifying the filtrate, it yielded the mucoid as a flocculent precipitate which could be filtered and then weighed.

The purpose of this work was to ascertain first, whether mucoid was completely precipitated by the addition of a slight excess of dilute acid to the mucoid solution (the solvent being half-saturated lime water). Secondly, we wished to find out whether albumins were precipitated from a mixture of albumin and mucoid, by acidifying the mixture in the cold. Thirdly, we wished to ascertain whether mucoid coagulated by being boiled in a neutral solution in the presence of neutral salts. And lastly, we wished to see whether the various precipitations of the mucoid sample showed any differences in nitrogen content; in other words we desired to examine the homogeneity of the various acid precipitates.

The mucoid used was from several beef tendons (Achilles), and was prepared by removing all water-soluble proteids by careful washing of the tendons in tap water. The tendons were then cut into thin slices transversly and again thoroughly washed with cold water. The next treatment was to allow the slices of tendon to extract with half-saturated lime water for a day. This extract was filtered and made slightly acid with .2 per cent. hydrochloric acid, using litmus paper as indicator. The solution, with a casein-like precipitate was allowed to stand a short time when the precipitate flocked together and settled to the bottom of the container, leaving a perfectly clear supernatant liquid.

The filtered residue was dissolved in half-saturated lime water, filtered through silk and again precipitated with an excess of .2 per cent. HCl. This precipitation and solution alternation was continued until the eighth precipitation, when this precipitate was filtered by decantation and the residue was thoroughly dried by standing with absolute alcohol. The powdery white precipitate was carefully filtered and pulverized, then further dried at 100-105° C. for several hours. The bottled sample so obtained was used in this set of experiments.

In the study of the complete precipitability of tendon-mucoid by means of dilute HCl, a definite amount (2 grams) of the dried sample was weighed and dissolved in a mortar with the least quantity of half-saturated lime water necessary, about 300cc. The solution was then filtered through silk and by means of a pipette, equal portions of the filtrate were removed to respective beakers and were precipitated by varying amounts of acid. This phase of the acid precipitation was subdivided into a study of the effect of dilution of the mucoid and the effect of the use of varying amounts of acid. In each case duplicate checks were carried along on the amount of actual mucoid present and precipitable under the most favorable conditions. In every instance the mucoid precipitated by the acid was filtered on weighed papers, dried at 105° C. for several hours and weighed on the paper. The paper and mucoid were then ashed and the ash deducted from the original weight on the paper. The acid filtrates, usually about 250cc. in volume, were poured into about five liters of strong alcohol, allowed to stand 24-36 hours and filtered on weighed papers. The precipitates were washed with strong alcohol, dried and weighed; the precipitates and papers were burned respectively, and the ash, ranging from a few tenths of a milligram to a hundred milligrams, was deducted in order to get a value for ash-free mucoid material.

As results of an extended investigation of the deportment of mucoid in a half-saturated lime water solution, with .2 per cent. HCl, it was found that not all the mucoid was precipitated under the best conditions. There was always 10 to 20 per cent. of the mucoid precipitated by the strong alcohol treatment and part, perhaps 8 to 10 per cent. of the original mucoid, was not precipitated by the acid nor alcohol treatment. It was found that the more concentrated the solution of mucoid, the more complete was the precipitation. The weaker the final acidity of the solution was with .2 per cent. HCl, the less complete the precipitation. The best results were obtained with a half-saturated lime water solution saturated with the

mucoid sample (about a 2 per cent. solution), the mixture diluted slightly and made acid enough to turn fresh litmus paper red immediately. This treatment yielded a solution that filtered readily (an item of vast importance with mucoid and other gelatinous solutions), that washed rapidly and gave a filtrate yielding the minimum quantity of mucoid with strong alcohol treatment. With the use of acetic acid instead of HCl, much more acid was required to precipitate any mucoid at all, and with an excess of acetic acid the results were very unsatisfactory, much more than with even a little dilute HCl.

In testing the action of dilute acid on a mixture of albumin and mucoid, the details were as follows: A standard solution of mucoid was made and equal amounts of the alkaline solution were placed in each of several beakers. The actual amount of mucoid added to each beaker was determined by duplicate checks. To the various beakers containing equal amounts of mucoid diluted to the same volume, varying amounts of meat extract were added. The meat extract was made in the laboratory by extracting fresh meat with cold water and filtering the proteid-bearing solution through silk. Duplicates were run on the meat extract and also on each of the mixtures of meat extract and mucoid. For preciptation, the same acidity was maintained in each beaker using .2 per cent. HCl as the reagent.

By way of results, although the meat extract alone yielded no precipitate in the cold, it was found that when mixed with mucoid, practically all the mucoid and some of the albumin separated. With increased non-mucoid proteid content, the weight of material precipitated by .2 per cent. HCl likewise increased. In fact, all the precipitates from the meat extract-mucoid mixture weighed more than the amount of mucoid which the solution was known to contain. All the precipitations were made in duplicate and found to check closely with each other, and each set of duplicates in the series varied approximately the same. By knowing the position of the set of duplicates in the series, one could closely approximate the actual weight before weighing. The experiments showed that the precipitation of mucoid in the presence of albumins was inaccurate for the determination of mucoid.

With the coagulation test for mucoid, the general opinion is that mucoid does not coagulate on boiling a neutral solution in the presence of salts. To test this, a solution of mucoid was prepared by rubbing up about 10 grams mucoid in a mortar with about a liter of half-saturated

lime water. When complete solution was attained, the alkaline solution was carefully neutralized with .2 per cent. HCl. The neutral point was determined by litmus paper that was fresh and quite sensitive. No mucoid precipitated in the neutral solution, but it was strained through silk for the sake of uniformity of conditions. Duplicate samples were taken to determine the mucoid content before heating. The major portion of the solution was gently boiled under a water condenser. Every half hour, about 100 cc. of the solution was removed, allowed to cool rapidly without any loss of water vapor, filtered and duplicate aliquot portions of the filtrate were used for acid precipitation of the mucoid content.

By way of results, it was noticed that continued boiling had a fatal effect on the mucoid. At first the solution became turbid. At the end of the first half hour's heating, there was a nice coagulum in the solution. This increased gradually until about the fourth hour, when there was a heavy coagulum throughout the solution. During the process of continued heating, the solution remained neutral without the addition of any alkali or acid. The longer the heating continued, the more rapidly the solution filtered. The first few filtrates were very slightly turbid, but the turbidity gradually decreased to water-clearness in the last few filtrates.

With regard to the filtrates, on treatment with dilute acid it was found that with the initial precipitations, less mucoid was recoverable than was obtained from the unboiled mucoid solution. The amount of mucoid precipitated gradually decreased as the experiment advanced and finally filtrates were obtained from which no mucoid could be precipitated with an excess of dilute acid. This was coincident with the heavy coagulum in the major portion of the solution. This experiment seemed to show conclusively that mucoid did coagulate on heating in the presence of neutral salts. It was deemed useless to try to separate a coagulable albumin from mucoid by this method.

The work done in this research was carried out, using a mucoid sample that had been purified by solution in alkali and precipitation by acid, this alternation for eight times. To test whether the eighth precipitate might be different from the sixth or tenth precipitate, or any other precipitate in the series, about 20 grams dry mucoid that had been precipitated probably twice, were dissolved in several liters of half-saturated lime water, strained through silk and precipitated with a slight excess of .2 per cent. HCl. This was filtered, dissolved and precipitated, the whole process being repeated fifteen times. Samples of the fifth, tenth and fifteenth precipitate were re-

moved, partly dried by standing in absolute alcohol, filtered and dried in an oven at 105° C. Duplicate Kjeldahl nitrogen determinations were made on each of the respective precipitates. Each of the six duplicates were found to check quite closely, thus indicating that there was nothing gained by the continued solution and precipitation of the mucoid. Incidentally it might be mentioned that there was mucoid lost at each precipitation by incomplete precipitation. This was evident from the fact that by most careful work, starting with 20 grams mucoid, it was only possible to wind up with about 13 grams actual dry mucoid.

In conclusion, it may be stated that tendon mucoid coagulates, the amount increasing with the duration of boiling, in the presence of neutral salts; that mucoid is not completely precipitated by an excess of dilute acid; that in a mixture of albumin and mucoid, most of the mucoid and part of the albumin are precipitated by dilute hydrochloric acid in excess.

As for a remdy, nothing is offered as yet, but this work seems to show that the older methods are inaccurate.

This work was carried on largely during the last year in the laboratories of the College of Physicians and Surgeons, Columbia University, New York, where the author was associated with Dr. William J. Gies, and under whose supervision the details were worked out. Owing to the non-possession of the actual notes at present, many valuable data must be left out of this paper, but every statement made can be further demonstrated by experimental data.

# THE ESTIMATION OF LEAD BY THE TITRATION OF LEAD CHROMATE.

BY W. C. BROOKS.

The first experiments were made to test the accuracy of the method. Weighed amounts of pure lead nitrate were dissolved in water and the lead was precipitated by potassium dichromate in slight excess. The lead chromate was filtered, was washed and was dissolved in hydrochloric acid. The resulting chromic acid was determined by adding potassium iodide and then by titrating the free iodine with sodium thiosulphate. The results of several titrations are given below:

| $Pb(NO_3)_2$ Used. Grams. | 0.2 $Na_2S_2O_3$ Used. cc. | Lead Found. Per cent. | Error. |
|---|---|---|---|
| 0.1 | 18.15 | 62.56 | +0.05 |
| 0.1 | 18.15 | 62.56 | +0.05 |
| 0.2 | 36.35 | 62.60 | +0.09 |
| 0.2 | 36.3 | 62.55 | +0.04 |

A method for the estimation of lead in ores was worked out from these results. Weigh out 0.2 gms. of the ore, dissolve in 10 to 15 cc. of nitric acid and evaporate almost to dryness. Add 50 cc. of water and 5 gms. of ammonium acetate and heat to boiling. Precipitate the lead from the boiling solution with a slight excess of potassium dichromate. Filter, wash and dissolve the precipitate with 20 cc. of 1:1 hydrochloric acid, the solution being received into the original beaker. Dilute the solution and washings to 150 cc., add 0.3 to 0.5 gms. of potassium iodide and titrate the iodine that is liberated with sodium thiosulphate.

The only element that has been found to interfere with this method is barium, which gives high results. Experiments are being carried on to obtain a simple means of removing this metal. Although the work upon this method is not complete, it promises to become an accurate and a rapid means for the estimation of lead in the presence of all of the common elements.

# An Evolution Method for the Determination of Sulfur in Sulfides and Sulfates.

By Frank C. Mathers.

The object of this research was to devise a rapid method for the estimation of sulfur in sulfates and sulfides, especially in the presence of such elements as molybdenum, which interfere with the precipitation of barium sulfate. The idea was to heat the material with some metal which would reduce all of the oxidized sulfur and then combine with it to form a sulfide. The rest of the method would coincide with the ordinary volumetric evolution method for sulfur in iron and steel.

Powdered potassium sulfate, containing 18.39 per cent. of sulfur, was used in these experiments. In each experiment, 0.2 gm. of the potassium sulfate was thoroughly mixed with the reducing metal and was placed in a crucible which was heated. Experiments with zinc dust as a reducing agent showed that it was impossible to reduce all of the sulfate at low temperatures and that at higher temperatures some sulfur was lost by volatilization along with the zinc.

| Gms. of Zn Used. | Temperature. | Per cent. of S Evolved. | Per cent. of S in the Residue. |
|---|---|---|---|
| 3.0 | Bunsen burner, 5 minutes. | 17.05 | 0.64 |
| 3.0 | Blast, 5 minutes. | 17.20 | 0.11 |

The use of a mixture of zinc and aluminum gave still poorer results. The addition of bases such as calcium oxide, calcium carbonate, sodium carbonate, or magnesium oxide were without beneficial effects. The use of some charcoal did not help.

Magnesium turnings gave the best results. To protect the porcelain crucibles, they were partly filled with 1.5 gms. of magnesium oxide and a cavity was made in this with the end of a test tube. The charge was placed in this cavity and was covered with 0.5 gm. of magnesium oxide. The porcelain crucibles, with well fitting lids, were heated for 5 minutes with a

Bunsen flame. A number of good results were obtained. Small amounts of sulfur remain in the residue in the evolution flask. The amount is apparently not constant and varies from 0.3 to 0.5 per cent.

These preliminary experiments have so far been just successful enough to encourage hope and call forth more work.

# The Destruction of Platinum Crucibles Through the Ignition of Magnesium Ammonium Phosphate.

By Robert E. Lyons.

Platinum is not oxidized in the air at any temperature, nor attacked by any single acid, yet there are many substances that attack and combine with it at comparatively low temperatures.

It sometimes happens that a platinum crucible is cracked or is fused through during the burning of the filter paper containing magnesium ammonium phosphate, or during the final ignition required to convert magnesium ammonium phosphate into magnesium pyrophosphate. This has again and again been a source of annoyance and expense to the phosphate analyst. The break down of the crucible is not due to invisible mechanical defects in the crucible, nor to the quality of the platinum or platinum alloy used in its construction. The cause of these occasional accidents is to be found in the reduction of the phosphate through incorrect procedure in burning or igniting the paper in connection with the precipitate, or, indirectly and less frequently, by failure to observe the well-established conditions for properly precipitating and washing magnesium ammonium phosphate.

The direction for the treatment of the magnesium ammonium phosphate residue given in the texts and handbooks, at the disposal of the writer, is by no means sufficient to enable the inexperienced operator to safely use a platinum vessel in this operation. The notes on the use and care of platinum ware, published by Baker & Co., Heraeus and other platinum smiths, do not suggest the possibility of a mishap from the ignition of magnesium ammonium phosphate in a platinum crucible. The notes furnished by the Baker Co. have long contained the statement: "Organic matter containing phosphorous should not be ignited in platinum dishes, as it affects the platinum seriously." This "serious affect" is the same as that noticed occasionally in connection with the ignition of magnesium ammonium phosphate in platinum crucibles, and is caused by the combination of reduced phosphorous with the platinum, forming platinum phosphide.

The reduced phosphorous unites with platinum even at a dull red heat (600° C.).

The external appearances of a crucible which has suffered such an attack are characteristic. Cracks of varying length appear, usually in the bottom, but sometimes in the sides; the fractured surfaces are distinctly crystalline; the edges of the fractures are usually raised and puffed and at times present unmistakable signs of fusion.

Reduced phosphorous, the immediate cause of the destruction of the crucible, may be accounted for by inquiry into the nature, the origin and the conditions governing the deportment of reducing agents which could act upon magnesium ammonium phosphate during the processes of incineration and ignition.

The reduction of the phosphate may be due to any or all of the following:

1. Carbon from the imperfectly ashed filter paper.

2. Ammonia liberated by heat from magnesium ammonium phosphate, or from sodium ammonium phosphate, or ammonium phosphate, which may be present in abnormal amount in the magnesium precipitate.

3. Hydrogen from the dissociation of ammonia at the high temperature, and also from the incomplete combustion zone of the gas flame by diffusion through the platinum crucible.‡

The reduction of magnesium pyrophosphate by carbon begins at 950° Cent. and becomes violent at 1,100 to 1,200° Cent.‡ The reduction by hydrogen begins somewhat below 900° Cent.‡ Dry ammonia gas passed over magnesium pyrophosphate heated to 950° Cent. yields phosphine and red phosphorous.‡ The destruction of the platinum vessel is most rapid when the residue contains free ammonium phosphate, which upon fusion yields most of its ammonia and meta-phosphoric acid. Ammonium phosphate heated in a covered platinum crucible to 700-800° Cent. causes complete destruction of the vessel. Holes appear in the bottom and sides, and the lid may fuse. The quantity of ammonia from the magnesium ammonium phosphate, which has been properly prepared, will prove destructive only under especially unfavorable conditions, e. g. very rapid heating of the phosphate to a high temperature.

Strict observance of the following summarized suggestions will insure the safety of the platinum crucible in the ignition of magnesium ammonium phosphate:

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Zeitsch. f. angew. Ch.

1. Precipitate the magnesium with sodium hydrogen phosphate, or with ammonium sodium hydrogen phosphate, rather than with ammonium phosphate.

2. Do not neglect to wash the precipitate with water containing one-fourth its volume of conc. ammonium hydroxide until the washings show but a faint turbidity with silver nitrate acidified with nitric acid. If ammonium phosphate is present thorough washing is particularly important.

3. Remove the main portion of the residue from the paper before incinerating, or burn the paper with a small residue, in the crucible, over a very small Bunsen flame. This may be quickly accomplished in a draught produced by tilting the lid of the crucible. *Do not ignite strongly nor heat to the fusing point of the phosphate until the material in the crucible is white (carbon free).* If the ashing of the paper has been imperfect, allow the crucible to cool, moisten the residue with a few drops of conc. nitric acid, cover the crucible with the lid, carefully evaporate the acid and heat again in the Bunsen flame. The process must be repeated until the residue becomes white.

4. To the residue in the crucible add the main portion of the precipitate and heat in the Bunsen flame gently at first, or until the greater part of the ammonia has been expelled, then heat strongly in the blast flame until the material ceases to decrease in weight.

# A Probable Origin of the Numerous Depressions in the Mesa South of the Arroyo Formed by the Outlet of Tijeras Canyon in the Sandias Near Albuquerque, New Mexico.

By Albert B. Reagan.

The occurrence of numerous slight depressions, thickly distributed over the mesa south of Tijeras arroyo on the east side of the Rio Grande, south of Albuquerque. New Mexico, is very noticeable. These were observed to be rarely more than five yards across and commonly from eighteen inches to two feet in depth and are provided with a raised border. They resemble buffalo wallows very much; but are too abundant and their distribution is too general. The stratum in which they are indented is a very loose, unlithified formation, superimposed upon the Albuquerque Marl,* a calcareous deposit some six feet in thickness.

The depressions extend in depth to this marl stratum and seem to hold water.

These depressions seem to be the "blowouts" of mud upheavels. They seem to have been formed at the time the Albuquerque marl was in a semifluid state. The loose unlithified stratum that is superimposed upon the marl was washed down from the Sandias onto the area faster than the marl could harden or "creep" from its advance over the bottom of the then Albuquerque lake which occupied the Rio Grande embayment at that point. As a result of the pressure caused by the superincumbent weight, mud lumps formed in size proportionate to the pressure, like those now forming in the Mississippi Delta.** And like those of the Southeast Pass of that delta, they collapsed on reaching the mature stage, leaving a small pit surrounded by a raised ring. Thus the mud lump, "blowout" theory seems to explain the origin of the depressions.

*C. L. Herrick. The Geology of the Environs of Albuquerque, New Mexico. American Geologist, Vol. XXII, pp. 29-33.

**E. W. Hilgard. The Exceptional Nature and Genesis of the Mississippi Delta. Science, Vol. xxiv, pp. 861-866.

# The Headwaters of the Tippecanoe River.

By J. T. Scovell.

The Wabash is the great river of Indiana. It rises in Ohio, flows westerly across Indiana, then southerly along the western boundary of the State into the Ohio River. The Tippecanoe River is the chief tributary of the Wabash from the north.

The Tippecanoe has its sources in two groups of lakes situated in the southwestern part of Noble County and in the northern part of Whitley County, Indiana.

Crane Lake and Crooked Lake, through short outlets, flow into Big or Tippecanoe Lake. Goose Lake, New Lake and Old Lake flow into Loon Lake. The outlet of Tippecanoe Lake flows westerly and northerly about two miles, where it joins the outlet of Loon Lake, forming Tippecanoe River. This stream flows northwesterly about five miles into Smalley Lake, and thence westerly 1½ miles into Baughner Lake, thence south of west through marshes and ponds 1½ miles into a mill-pond, called "the Dam;" thence northwesterly through Kaiser Lake, the Backwater and the Channel about 3½ miles into Boydstone Lake, in the eastern part of Kosciusko County; thence westerly about two miles into Tippecanoe Lake, of Kosciusko County.

Through the greater part of this distance there is quite a distinct valley. It varies greatly in width and in the hight and steepness of its bluffs. This valley, these lakes and ponds, the marshes and connecting streams are in or on a mass of glacial materials that was probably deposited from the Erie Lobe of the continental ice sheet. These materials help to form what Frank Leverett calls the Mississinewa Moraine. This moraine extends from White County northwestesly to Steuben County. It covers Noble County and large parts of Steuben, Lagrange, Dekalb, Whitley, Kosciusko, Fulton, Wabash, Miami, Cass and White counties. It includes the northern portion of Dr. C. R. Dryer's Mississinewa—Eel Moraine.

Dr. Dryer says "it is an irregular, variously undulating pile of clay, sand, gravel and boulders, with a total thickness of from 200 to 485 feet.

Its topography defies verbal description, but may be included under a few general types. The greater part of the area may be designated as *crumpled*. The ridges have no particular direction, their tops are broad and slopes gentle, yet there is very little level ground. This type passes by insensible gradations into the *corrugated*, in which the ridges are steeper, sharper and arranged in somewhat parallel lines. Similar features much exaggerated produce what may be called *gouged* or chasmed regions. The surface is entirely occupied by deep, irregular, elongated valleys with narrow, sharp, winding ridges between, all in indescribable confusion, and everywhere ponds and swamps, marshes and lakes." The greater part of the lakes of Indiana are in this moraine. The Pigeon, Fawn, and Elkhart rivers drain a large section of this moraine into the St. Joseph of Lake Michigan. Cedar Creek drains a small portion into the St. Joseph of Lake Erie; while the Eel and Tippecanoe rivers drain the balance into the Wabash.

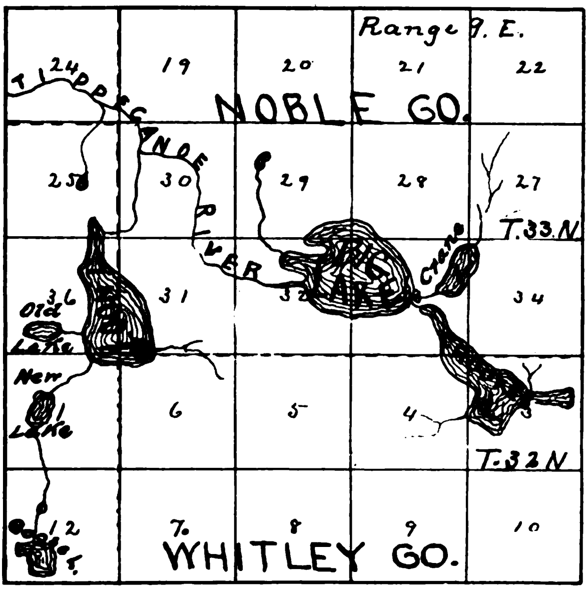
## CRANE LAKE.

Crane Lake, 30 to 35 acres in extent, lies mainly in the N. E. ¼ of Section 33, Town 33 north, Range 9 east, Noble County, Ind. It is nearly a half mile long from N. E. to S. W. and about 40 rods wide. It is surrounded by marsh and swamp on all sides. Its chief tributary is a little stream about a mile long from the northeast, which drains the W. ½ of Section 27. Its outlet is by a ditch across a swamp westerly about ¼ of a mile into Big Lake. The banks and surrounding regions are not more than ten feet above the water of the lake and before ditching they were probably not more than four feet above the water. The bottom is of soft mud and the slopes of the bed are rather abrupt, except in the southwest. Soundings at intervals of about 100 feet, commencing on the northeast. were as follows: 50 feet out, 15 feet deep; 150 feet out, 19 feet; then 15, 20, 24, 26, 32, 32, 30, 23, 26, 20, 19, 19, 19, 18, 17, 15, 10, 10, 10. 10, 10 feet, and 1 foot in the outlet ditch.

## CROOKED LAKE.

The eastern extremity of Crooked Lake is in the southeast corner of the N. E. ¼ Section 3, T. 32 N., Whitley County, Ind. It extends northwesterly about 1½ miles into the S. E. ¼ Section 33, Noble County, and has an area of about 300 acres. A ridge about ¼ mile wide and 18 feet high divides the east end of Crooked Lake from Cedar Lake which drains into Eel River. About the northern part of the lake there is considerable

low, swampy land, and the country back of the swamp rises scarcely ten feet above the lake. Farther south clay hills rise abruptly to an elevation of 25 or 30 feet on both sides of the lake. The road running N. and S. east of the lake crosses five massive clay ridges trending east and west within a mile, each rising 30 feet or more above the lakes. There are three small islands and considerable shallow water in the southwestern part of the lake and the northern




part is rather shallow, but fully one-half the area is covered with deep water. The area drained into the lake is very narrow. I saw only one inlet and that was short and small. Soundings, at intervals of about 80 feet, commencing on the east and following the axis of the lake, were as follows: 24, 30, 30, 30, 30, 36, 42, 36, 36, 30, 24, 21, 18, 9, 6, 4, 4, 6, 6, 18, 21, 27, 33, 39, 45, 45, 45, 45, 39, 42, 60, 75, 81, 81, 84, 87, 90, 95, 96, 102, 102, 102, 105, 106, 106, 105, 105, 106, 105, 105, 105, 105, 96, 93, 93, 96, 99, 93, 81, 81, 81, 96, 99, 100, 99, 96, 99, 84, 75, 54, 42, 21, 27, 30, 42, 45, 45, 48, 45, 42, 36, 30, 27, 27, 27, 30, 30, 27, 27, 21, 15, 12, 12, 12, and 4 feet among the lily pads near shore.

Going east on the county line, at intervals of 160 feet, I found water 66, 96, 96, and 66 feet deep.

The lake is well stocked with fish—bass, bluegills, perch, grass-pike, and others. Under much of the shallow water there is an abundance of workable marl.

## TIPPECANOE LAKE, OR BIG LAKE, NOBLE COUNTY.

This lake occupies parts of sections 28, 29, 32 and 33, Town. 33 N., Range 9 east. It formerly had an area of about 400 acres, but a ditch has lowered the water about 7 feet and reduced the area to about 300 acres.

Before ditching, fully one-half the area was less than 10 feet deep. There is still considerable shallow water in the southeast and southwest portions of the lake, but much the greater part of the area is deep water. The bluffs are low, not more than 10 to 15 feet above the water. The ditching caused the destruction of a great mass of vegetation, and so changed the environment of another great body of plant life that it will be many years before the vegetation can adjust itself to the changed conditions and reach a stable equilibrium. At its present level the lake cannot support as much vegetation as formerly. The lake is famous for the quantities of fish found in its waters, but they are not as plentiful as formerly. On the southwest we found water 30, 35, 46, 47, and 36 feet deep, and going northwesterly along the axis of the lake at intervals of about 200 feet we found water 50, 65, 72, 65, 50 and 38 feet deep. Deeper water was claimed, but we could not find it. There is considerable marl in the lake bed, but it is not a workable deposit.

## GOOSE LAKE.

This lake is in the southwest ¼, section 12, Town 32 N., Range 8 E., Troy Township, Whitley County. It has an area of about 150 acres. It is surrounded by considerable swamp and low land, in which are several small ponds. Back of these are several morainic hills rising from 30 to 50 feet above the surface of the lake. The slopes of the lake bed are rather steep and the water is in general quite deep. The lake has been lowered about 6 feet by a ditch. This drained adjacent swamps but lessened the area of the lake by only a few acres. Fishing is said to be fairly good. Commencing on the south and going northerly and westerly at intervals of about 100 feet we found the depth as follows: 100 feet out, 17, 20, 29, 30, 34, 34, 34, 37, 37, 41, 50, 54, 57, 62, 63, 62, and 61 feet; westerly,

53, 37, 37, 30, 31, 35, 38, 37, 36, 42, 50, 45, 37, 28 and 14 feet about 75 feet to shore. In the western part of the lake south of the line of soundings just given we found water 45, 57, 62, 54, 35, and 25 feet to south shore. The outlet ditch runs northerly from the northwest part of the lake, into Dollar Lake, thence into New Lake.

## NEW LAKE.

New Lake, having an area of about 60 acres, is situated near the center section 1, Troy Township, about 1½ miles north of Goose Lake. It is surrounded by low, gently sloping hills, and is bordered on the east by broad areas of *Scirpus americana* and *Scirpus lacustris*. Commencing at the southeast and going northerly at intervals of about 100 feet, we found soundings as follows: 15, 12, 20, 39, 30, 29, 30, 31, 38, 43, 38, 34, 26, 23, 21, 22, 23, 26, 36, 37, 34, 31, 21, and 6 feet among the lily pads near shore. The outlet is by a ditch northeasterly about half a mile into Loon Lake.

## OLD LAKE.

Old Lake, about the same size as New Lake, is situated about a half mile north of New Lake in the S. W. ¼, Sec. 36, Town. 33 north, Range 8 east, Etna Township, Whitley County. The shores are low and swampy or marshy. Considerable areas of swamp land to the west drain into Old Lake. The outlet is easterly a half mile or so into Loon Lake. Soundings at intervals of about 100 feet, going easterly, as follows: 25 feet out, 12, 30, 31, 31, 31, 27, 27, 32, 40, 42, 45, 45, 45, 43, 37, 34, 30, 28, 25, 21, and 15 feet 100 feet to shore.

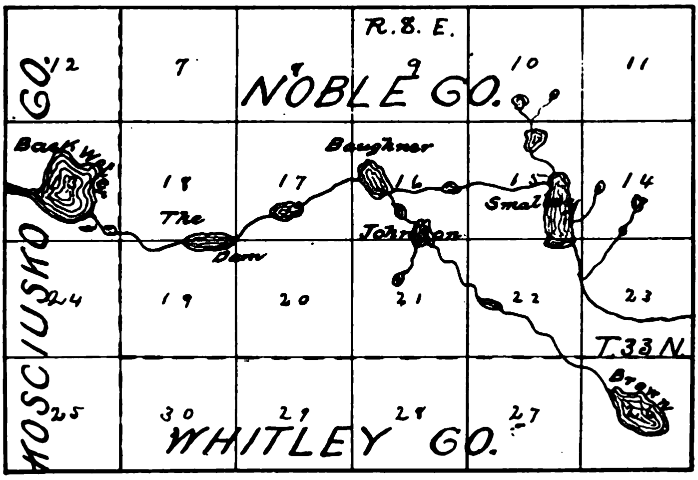
## LOON LAKE.

Loon Lake lies mainly in the east half of Sec. 36, Etna Township, Whitley County, and in the west half of Sec. 31, Noble Township, Noble County. It has an area of about 240 acres. A drainage ditch lowered the level of the lake about 7 feet, greatly lessening the area, and reducing the proportion of shallow water. Lowering the lake uncovered large areas of muck, marl and sand. Some of the muck is well covered with vegetation, but the sand and marl are still quite barren after six years of exposure. There is considerable marsh land and swamp in the west, but on the south, east and north there are low bluffs rising 10 to 15 feet above the lake. To the northwest of the lake there are some hills that rise fifty feet above the lake. Commencing at the south and working northerly along the axis of the lake at intervals of about 136 feet we found depths as follows:

136 feet out, 18, 42, 39, 24, 39, 48, 57, 66, 66, 81, 75, 63, 51, 36, 33, 54, 36, 30, 21, 18, 21, 33, 36, 39, 36, 36, 33, 24, 27, 39, 42, 48, 48, 36, 27, 27, 33, 33, 18, and 2 feet among the lily pads. Going north from island about 40 rods east of the above line we found, 150 feet out, 15 feet, and at intervals of 136 feet, 36, 48, 54, 54, 33, 57, 63, 60, 60, 57, 39, 27, 24, 27, 33, 36, 51, 54, 45, 33, 33, and 18 feet 136 feet to shore. Going westerly from the island, at intervals of about 136 feet, as follows: 21, 24, 27, 39, and 57 feet, near station 7 on first line, 60, 93, 93, 93, 93, 81, and 48 feet, the water shoaling rapidly to the west.

The soundings show a large area of deep water and a very uneven bed. Fishing is fairly good but not as good as before the lake was drained.

The outlet flows from near the north end of the lake easterly a few rods, then north a half mile or so, where it joins the outlet of Tippecanoe Lake, forming Tippecanoe River, which flows westerly into Smalley Lake, draining on the way considerable areas of marsh and swamp.




## DOLLAR LAKE.

This lake, having an area of 12 to 15 acres, is situated near the center of Sec. 25, a little northwest of Loon Lake. Hills rise abruptly from the shore of this lake to an elevation of about 50 feet. A narrow zone of marsh surrounds the lake. The slopes of the lake bed are steep. The

soundings were 26, 30, 37, 44, and 51 feet. The water was reported much deeper, but we found only 51 feet. The outlet is northerly into the river in the S. E ¼ Sec. 24.

SMALLEY LAKE.

Smalley Lake, having an area of about 80 acres, lies mainly in the S. E. ¼ Sec. 15, extending a little way into the N. E. ¼ Sec. 22, Washington Township, Noble County. There is considerable low land on the south and east, with low bluffs 12 to 20 feet on the west and northwest. A little stream drains three small ponds and some marsh land into the northern part of the lake and two ponds with some low land on the east are drained into the lake or the river just south of the lake. Commencing at the inlet and going northwesterly we found at intervals of about 100 feet water as follows: In mouth of inlet, 1 foot; 100 feet out, 8, 16, 28, 35, 37, 37, 38, 38, 39, 39, 39, 40, 40, 39, 39, 38, 38, 38, 39, 40, 42, 38, 32, 21, 25, 25, 20, and 12 feet; 3 feet near the head of the outlet, water in the outlet about 8 inches deep and 10 feet wide. From Smalley Lake near the center of Sec. 15 the river flows westerly about 1½ miles into Baughner Lake, draining on the way a wide tract of low swamp land and Gallup's pond or lake, having an area of about three acres, near the center of Sec. 16. It is reported to be shallow.

BAUGHNER LAKE.

This lake is located just west of the center of Sec. 16 and has an area of about 30 acres. We did not make any soundings in this lake. It is reported as rather shallow, not more than 20 to 25 feet. Baughner Lake receives considerable water from the southeast through Johnson Lake and its tributaries.

BROWN LAKE.

Brown Lake is in the center of section 26, Town. 33 N., Range 8 E. It has an area of about 30 acres. It is somewhat elliptical in form, being longer from southeast to northwest. Commencing on the southeast, at intervals of about 100 feet, we found water as follows: 100 feet out, 21, 29, 39, 47, 48, 44, 46, 46, 46, 42, 37, 31, 29, 26, and 21 feet, and 6 feet in the lily pads about 20 feet from shore. There is some swamp land to the southeast and considerable marsh land on the north, but the zone of wet land is narrow on the south. The slopes are gentle on all sides, the highlands rising to 20 to 30 feet above the lake. The slopes of the lake bed seemed to be abrupt on all sides. The lake is drained northwesterly by

a ditch into McDonald Lake or pond, in the western central part of Sec. 22, thence northwesterly into Johnson Lake, on the north line of Sec. 21, which has an area of about 10 acres. Water is reported deep, 30 to 35 feet. Baker Lake or pond, a little northwest of the center of Sec. 21, drains into Johnson Lake. The outlet of this lake flows northwesterly through a pond and surrounding marsh into Baughner Lake. The outlet of Brown Lake drains a wide area of land, but there is considerable wet land along this valley that the present ditch does not drain. Two other ponds in Sec. 16 are drained into Baughner Lake. From this lake the river runs a little south of west about 1½ miles into "the Dam," a pond on the line between sections 18 and 19, so that it is in the S. E. ¼ Sec. 18 and N. E. ¼ Sec. 19. It has an area of about 15 acres and was formed by a dam about 10 feet high. It is shallow and abounds with vegetation. From "the Dam" the river flows westerly and northwesterly through Keiser Lake, small and shallow, into the Backwater, a shallow body of water occupying a large part of the south half of Sec. 13, Town. 33 N., Range 7 W., Kosciusko County; thence northwesterly through "the channel" into Boydstone or Webster Lake, in sections 10, 11, 12, 14 and 15, Tippecanoe Township, Kosciusko County, Ind.

# Caves and Cave Formations of the Mitchell Limestone.

By F. C. Greene.

## THE MITCHELL LIMESTONE.

The Mitchell limestone, otherwise known as the St. Louis, barren, or cavernous limestone, is a bluish or grayish, hard, compact, even-grained stone, generally having a conchoidal fracture. It is so compact as to make it rather impervious. Intercalated layers of blue-gray shale are frequent. Large concretions or chert are characteristic of certain horizons. When the stone weathers, these masses of chert do not dissolve, but break into more or less angular fragments which strew the ground over the Mitchell area. In Indiana the formation is also characterized by the common presence of a genus of corals known as *Lithostrotion* or *Lonsdaleia.* In some places, such as western Monroe or southern Crawford County, there is a typical white oölite found near the top of the formation.

Analysis shows the Mitchell to be a very pure calcium carbonate, and at Mitchell, Lawrence County, from which place the formation received its name, it is extensively quarried for making lime and cement.

It is found in Harrison, Floyd, Crawford, Washington, Orange, Martin, Lawrence, Monroe, Greene, Owen, Morgan, Putnam, Parke, and Montgomery counties.* It extends south into Kentucky and west into Illinois, where it exhibits similar characteristics.

In the southern part of the State it reaches a thickness of 350 to 400 feet; in the central part of its area, that is, in Lawrence and Monroe counties, the thickness is from 150 to 250 feet, and from here gradually thins toward the north.**

The greater part of the Mitchell lies in the non-glaciated portion of the State, thus exposing an erosion topography unaffected by other agencies. Several factors enter into the cause of its present topographic aspect. During Cretaceous time the area in which the Mitchell is located was eroded to base level, forming part of the great Cretaceous peneplain. After this event had occurred, a period of elevation began so that erosion

*Hopkins, T. C., 28th An. Rept. Ind. Dept. Geol., p. 57.
**Op. cit., p. 58.

again commenced to cut down the surface, and probably during the Tertiary period, it again reached partial peneplanation with a few monadnocks here and there standing above the general surface. It is this Tertiary peneplain which gives the country its level appearance when viewed from a distance. Since this second peneplanation, the country has probably been relatively elevated to the present time. The western edge of the Mitchell area is overlain by the Huron formation, which, by reason of its hard and soft strata, has taken on a very rugged aspect. To the east of this belt level lies the central or slightly rolling area of the Tertiary peneplain, while to the east of this, the eastern edge again becomes rolling, owing to the underlying Salem and Harrodsburg limestones.

The Mitchell has a dip to the southwest which probably averages 20 to 30 feet to the mile. This affects surface streams, though these are very few, owing to the extensive underground drainage.

The general relief of the surface of the Mitchell area becomes greater toward the Ohio River. This is probably due to at least three causes, namely, the dip to the southwest, the increasing thickness of the formation, and the fact that the Ohio River is the largest stream draining the area and has cut down to the lowest level of any stream in the area under consideration. In the vicinity of Wyandotte Cave the general level of the upland is about 300 feet above the level of Blue River.

The Mitchell limestone has long been known as the "Cavernous limestone." Both the Wyandotte Cave of Indiana and the Mammoth Cave of Kentucky occur in its strata. In three counties in the vicinity of Mammoth Cave, over five hundred caves are known to exist. These facts lead us to investigate the general adaptibility of this limestone to cave formation.

The reasons of this adaptibility are numerous. Besides the bedding planes, two sets of vertical joint-planes exist, one set having a general east and west direction and the other a north and south direction. Vertical joint-planes are probably more numerous in this, than any other of the Mississippian limestones. Owing to the fact that the Mitchell is rather impervious and often of a lithographic nature, the down flowing water is forced to follow the joint and bedding planes. The underlying Salem limestone contains joint-planes but is porous enough to become thoroughly saturated instead of confining the water to joint-planes.

The Mitchell limestone has a great thickness of rocks of nearly uniform texture. It is composed of nearly pure calcium carbonate, which renders

it soluble to meteoric water. Many of these facts are brought out by Cumings in his paper, "On the Weathering of the Subcarboniferous Limestones of Southern Indiana," in the Proceedings of this society for 1905, pages 85-100. The great central area is practically level, owing to Tertiary peneplanation, thus lessening the amount of run-off. The western part of the area is overlain by the Huron formation, composed largely of porous sandstone which absorbs precipitation and passes, a part of it, at least, downward into the underlying Mitchell. The area as a whole is wooded, which also tends to hold meteoric water rather than to give it up to such surface drainage as exists. The area in Indiana lies in a section of country which is one of relatively great humidity.

The individual layers of the formation are comparatively thin and are generally separated by thin layers of impervious shale. This factor tends to weaken the layers when a cave is formed beneath them and allows them to collapse, thus giving the stream the opportunity of enlarging the cave in a mechanical way by removing the debris.

## FORMATION OF CAVES.

Limestone ($CaCO_3$) is only slowly and difficultly soluble in pure water, but when water descends through the atmosphere as in rain and snow, a certain per cent. of $CO_2$ is dissolved, forming $H_2CO_3$. This is enabled to dissolve calcium carbonate, forming calcium bicarbonate thus: $H_2CO_3 + CaCO_3 = CaH_2 (CO_3)_2$. The latter product remains in solution until evaporation takes place. It is owing to this fact that stalactites and stalagmites are formed in caves.

Now when rain-water falls on an area such as that underlain by the Mitchell limestone where the conditions favor a minimum amount of run-off and evaporation, and where the greater amount of precipitation soaks into the soil, it will tend to collect and flow downward through the most available passages. Such passages are furnished by the above-mentioned joint-planes. Where two of these joint-planes cross at right angles, the passage will be freest and it is probably at such points that most of the ground-water passes downward. This downward flow of water may be arrested by several causes, four of which are most important. The joints become tighter as they descend into the earth; the level of ground-water, where the flow in the joints is retarded, may be reached; an unusually impervious layer of limestone or shale may be present; or what is probably most important, a level corresponding to that of the local base level

of erosion may be reached and divert the downward moving water. Any or all of these causes may change the downward flow of water into lateral flow, although in time they may cease to have this function, owing to chemical or mechanical erosion.

Locally other factors may enter into the stoppage of the downward flow. These may be greater hardness or impurities of the limestone, etc.

The horizontal flow will naturally follow the line of least resistance, which will be along the line of one of the joint-planes. Thus young caves and many which are older, follow approximately straight north and south, and east and west lines and have right-angled turns. The direction of the cave stream will be determined by local conditions, such as hardness, dip, solubility and nearness to surface streams.

At first the erosion will be by solution, but in time the cave stream will come to be governed by much the same laws as surface streams and corrosion will do its share in enlarging the cave. The original downward opening will become larger and surface material with its hard, angular pieces of chert, and soil will be washed into the opening, and sinkholes such as are characteristic of the Mitchell area, will be formed. In time these become very large, occasionally containing many acres; however, it may be said that the very large sinkholes (and these only) are formed by collapse of caves.

In the young cave there will be no evidence of any erosion except that by solution. The water is very clear and contains a minimum amount of solid matter; the cave will be bounded on all sides by solid rock walls and angular protuberances will be everywhere conspicuous.

So much for the common type of a very young cave. A multitude of factors determine the size and shape of a cave as it grows older. Much depends on the level of the surface stream into which the cave stream flows. If the surface stream is much lower than the level on which the cave stream flows, the latter will cut down rapidly, other things being equal, thus forming a narrow and deep cave such as is seen at the entrance of Shawnee Cave in Lawrence County, or in Wyandotte Cave. If the level of the surface stream is near that on which the cave stream flows, the tendency will be toward lateral erosion, and the cave will cut downward only as rapidly as does the surface stream of which it is a tributary.

Most of the surface streams and probably all of the cave streams of the area had their origin since the Tertiary peneplanation. The Mitchell area has been elevated since then, as was mentioned above, but owing to

the fact that this elevation has been more or less interrupted, the surface streams have devloped terraces and the caves near the Ohio and its older tributaries have in some cases four or five levels, probably due to the same cause. Only the lowest of these levels will contain water at the present time. The four or five levels of passages in caves in the region under discussion may have had other local causes, such as differences in hardness or solubility, etc. It is not meant that all caves in this region have several levels, for new caves are continually being formed.

The bedding planes being planes of weakness, the cave will be broader at the bedding planes than between them. (Fig. 1.) Softness or unusual solubility of a particular layer will cause a broadening of the cave, while hardness or insolubility will result in a narrowing. If a cave is following some particular joint-plane, a cross joint (which perhaps carries a larger or smaller stream) will cause a decided broadening, due to the weak spot caused by the cross-joint.

When a particular cave stream reaches temporary base level it will cease downward cutting and begin eroding laterally. In this case the stream is generally supplied with abundant abrasive material. In time this will produce a cave with a sort of an inverted T-shape. (Fig. 2.) Owing to the thinness of the layers, in time this will cause a collapse of the sides and roof, such as has taken place in many parts of Wyandotte Cave. (Fig. 3.)

If such action takes place where two joints cross, the amount of rock precipitated from the roof and walls will be enormous, producing such a mound as Monument Mountain in Wyandotte, where a mound over one hundred feet high has been formed. In the upper part of Shawnee Cave, Lawrence County, the lateral erosion has been very great and in some places in this and also in Wyandotte Cave, this tendency has resulted in the collapse of the floor of an older passage above. Thus it will be seen that the floor of an old cave will be apt to be rough and rocky instead of level, although there are cases where the stream has suddenly found another outlet, leaving an old cave with a smooth and firm floor.

Most of the old caves and some of the younger do not follow straight cardinal lines or have right-angled bends. In young caves this is due to a tendency of the stream to straighten its course just as a surface stream does, although hardness and solubility of the rock play a large part. (Fig. 4.) For example, if on one side of a joint-plane which a cave stream is following, there is a particularly soluble spot, there will probably be a

bend or curve developed at the soluble place. (Fig. 5.) In old caves these factors, together with that of collapse from lateral erosion after base level has been reached, change the shape so that a straight line or right-angled bend is seldom seen.

### SPECIAL PHASES—PITS AND DOMES.

Many caves are characterized by pits and domes. The former may be formed in two ways. Where there is a particularly soft or soluble place in the floor of a cave, the hard, angular fragments of chert will congregate, and by a whirlpool-like abrasion and solution, a pot-hole will be produced. These sometimes reach large dimensions, as in Wyandotte, where pits twenty or thirty feet deep have been formed. In one particular passage of Wyandotte, the downward erosion has been very rapid, so that the stream has cut down to a lower level, leaving several natural bridges of solid rock.

The second type of pit and the domes are related. Often where two sets of vertical joint-planes cross, the water trickling down will dissolve out an erosion dome. In Mammoth Cave of Kentucky, these domes often reach a height of one hundred feet or more. They may be formed down to the level of the passage along one of the joints, in which case they are simply domes, or they may continue eroding after one passage has been deserted by the stream and continue to erode to a lower level occupied by another stream, thus forming a pit or dome according to the level from which they are viewed. (Figs. 6 and 7.)

### CAVE ENTRANCES.

Cave entrances may be formed in four principal ways. A sink-hole may become large enough to serve as an entrance, either by corrosion and solution, or by subterranean solution of the dome-forming type. Ropes, ladders, or steps are generally needed in this type of an entrance. The entrances to Little Wyandotte and Marengo caves of Crawford County are of this type.

Another and common type of entrance is that by way of the mouth of the out-flowing cave stream. In a young cave this is apt to be on the horizontal; but when one mouth is abandoned for another at a lower level, weathering produces a curious change. The rocks above the cave mouth will weather and fall to the floor, thus causing the entrance to progress up the slope and a great pile of debris to collect on the original floor of the cave. (Fig. 8.) The entrances to Wyandotte and Saltpeter caves

of Crawford County, and Mammoth Cave of Kentucky are of this type. A shaft was sunk to the depth of sixty feet at the mouth of Wyandotte before the solid rock floor was reached.

A cave stream may undermine the rock beneath a low place such as a sink-hole, causing the overlying strata to collapse. In this case there will be two entrances at the place where the cave-in occurred. Should atmospheric agencies weather back the two entrances the cave stream will flow above ground for a greater or less distance. This action has occurred twice in Shawnee Cave, Lawrence County, and the surface portions of Lost River, Orange County, have probably come about in an analogous manner.

A fourth type of cave entrance is that produced by a surface stream eroding its way into a cave; but this type is probably common only in regions of great relief, such as those bordering the Ohio, since surface streams of sufficient size to accomplish this are rather rare in the Mitchell belt.

MATERIALS DEPOSITED IN CAVES AFTER FORMATION.

It was stated in the second portion of this paper that calcium bicarbonate $(CaH_2(CO_3)_2$ was formed by the action of atmospheric water on limestone. This substance will remain in solution until evaporation takes place, when it will split up as follows: $CaH_2(CO_3)_2 = CO_2 + H_2O + CaCO_3$. The carbon dioxide being 1.5 times as heavy as air sometimes settles in the lower portions of caves, rendering them dangerous, but this is not often the case in the caves of the Mitchell area owing to the presence of air currents which remove the gas. The $CaCO_3$ will remain as stalactitic and stalagmitic deposits. Owing to the fact that in the lower and younger parts of the cave, which contain water, the air is generally saturated so that evaporation is at least not rapid, the calcareous deposits are found in greatest abundance in the higher and drier passages.

In the deposition of calcareous material the joint-planes again play a prominent part, due to the fact that water is able to find its way down through them. Very often the vertical joint along which a cave was formed will be marked overhead by a row of stalactites and sometimes by a row of stalagmites on the floor beneath. Where two joints cross each other the deposition is apt to be greatest. In Wyandotte cave in two places where large piles of rock have fallen (Senate Chamber and Monument Hill) owing to cross joints, the piles of rock are crowned with large stalagmites directly beneath the crossing of the vertical joints.

Often the water does not evaporate right at the base of the joint but trickles down the side walls, depositing a coating of calcareous material there.

In Milroy's Temple, Wyandotte cave, and in Shawnee cave, Lawrence County, the evaporation has not always taken place at the lower end of the stalactite, but they are curved outward and upward. This is possibly due to the twining tendency in the crystallization of the calcite. Local conditions may give rise to an almost endless variety of these calcareous deposits.

Under certain conditions gypsum and epsomite are deposited in caves, the former as a coating of the walls and as curved crystals or "Oulopholites," and the latter as delicate needle-shaped crystals in the earth of the cave floor. H. C. Hovey in the "Manual of the Mammoth Cave of Kentucky" states that the black deposit on the ceiling of the Star Chamber of this cave is the oxide of manganese. All of these materials are derived from the Mitchell limestone, but owing to its purity are not nearly in such great abundance as the calcite deposits.

The materials deposited on the floors of caves are generally of three classes: fallen rock, chert gravel and nitrous earth. Of the first class there is little to be said, as it has already been mentioned. The chert is derived from the concretions of chert in the limestone. Owing to its insolubility, it remains after all other materials have been dissolved. In Shawnee cave, Lawrence County, it has in places been cemented together by calcite and some oxide of iron to form a hard, firm conglomerate.

The nitrous earth or "saltpeter dirt" is practically always found in passages now abandoned by the streams which formed them. It seems to have been originally the finer portion of the solid matter carried by the cave stream. Some slackening of the current, probably due in most cases to fallen rock, caused this material to be deposited. The deposition then continued until the stream found another outlet. Another source of this fine earth, and probably equally as important, is that of material washed in through crevices and small sink-holes to the passages directly beneath them, which, of course, would be the higher passages of the cave. Now these high and dry passages are the ones most liable to be frequented by bats, and it is probably from the dung of these animals, which, according to Hahn,* spend about five-sixths of their existence in a dormant state, that the potassium nitrate is derived. Inspection of the earth in a

* Hahn, W. L., Some Habits and Sensory Adaptations of Cave-Inhabiting Bats. Biol. Bul., Vol. XV, No. 3. Aug. 1908, p. 190.

dry passage of Shawnee cave, Lawrence County, revealed a multitude of bat bones scattered through this earth, a fact that seems to confirm this theory.

In conclusion it may be stated that local causes may and often do exist that affect the formation of a particular cave and that are diametrically opposed to the factors enumerated above, so that no set of rules or conditions can be formulated for determining the formation of a cave or explaining its formation.

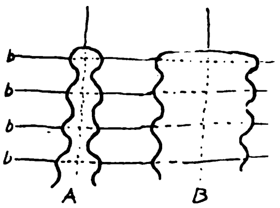



Fig. 1. Showing the effects of bedding planes where the stream has cut down rapidly (A) and slowly (B).

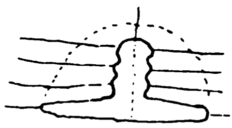


Fig. 2. Showing the effect of long continued lateral erosion. The dotted line shows the curve of greatest strength.

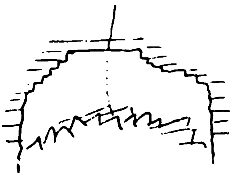


Fig. 3. Showing collapse due to weakness from lateral erosion. The cave has assumed the curve of greatest strength.

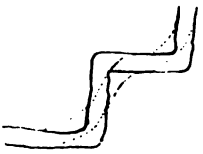


Fig. 4. The solid lines show the original cave and the dotted lines the course the stream will seek to pursue.

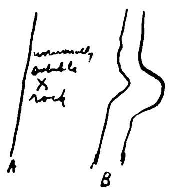



Fig. 5. Effect of unusually soft or soluble rock.

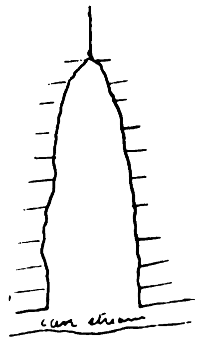


Fig. 6. Dome.

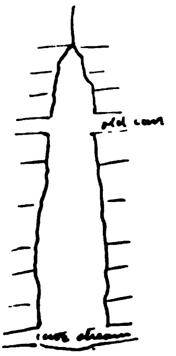


Fig. 7. Pit and dome.

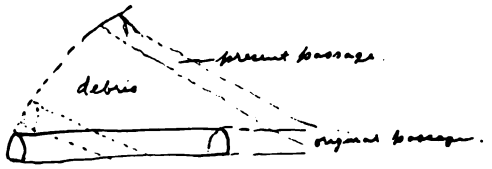



Fig. 8. Progression of a cave entrance up a slope.

# The Life Zones of Indiana as Illustrated by the Distribution of Orthoptera and Coleoptera Within the State.

By W. S. Blatchley.

During the past twenty years much of my spare time has been devoted to the collecting and classification of the insects of Indiana, especially Orthoptera, or katydids and grasshoppers, and Coleoptera, or beetles. In the report of the Department of Geology for 1902 the results of the work on Orthoptera were published, about 150 species being therein classified and described. The Coleoptera are at present being worked up, and I hope to be able to publish a descriptive catalogue of them within the next two years. Up to the present about 2,700 species have been collected in the State.

The collecting and detailed study of the distribution of the above mentioned insects in Indiana has developed certain facts regarding the life zones of the State which I thought might be of interest. In a map accompanying his paper entitled "Life Zones and Crop Zones of the United States," published in 1898, Dr. C. H. Merriam, chief of the Biological Survey of the U. S. Department of Agriculture, showed the "Upper Austral Zone" as covering the entire State with the exception of a very small area of the Lower Austral in the extreme southwestern corner. The facts brought out regarding the distribution of Orthoptera and Coleoptera in Indiana, which are supplemented by numerous field notes on other groups of insect and animal life, and on the flowering plants, prove conclusively that the "Transition Zone," represented by the Alleghanian fauna and flora, overlaps the northern fourth of the State, while the "Lower Austral Zone," represented by the Austroriparian fauna and flora, overlaps the greater part of the southern third. The Carolinian fauna and flora of the Upper Austral embraces, of course, the prevailing forms of life in the State, 93 of the 148 species of Orthoptera belonging to it. The majority of these range over the entire State, mingling with the representatives of the Alleghanian fauna in the north and with those of the Austroriparian fauna in the southern third. The proportion of Coleoptera belonging to

the Carolinian fauna will be about the same, but the exact figures cannot as yet be given. To the Carolinian fauna belong also the great majority of the other forms of animal life in the State.

As some members of the Academy may not be acquainted with Dr. Merriam's paper I would state that he divides the continent of America, according to the distribution of its animals and plants, into three primary transcontinental regions, viz., Boreal, Austral and Tropical. The Boreal region covers the whole of the northern part of the continent from the Polar sea southward to near the northern boundary of the United States, and occupies also the higher parts of the three great mountain systems, viz., the Sierra-Cascade range, the Rocky and the Alleghany mountains.

The Tropical region is represented in the southern part of the peninsula of Florida only. The Austral occupies the intervening territory, covering the whole of the United States and Mexico except the Boreal mountains and Tropical lowlands.

Each of these three great regions is again subdivided into a number of minor belts or areas, known as zones, and characterized by particular associations of animals and plants, the Austral region, which alone is represented in Indiana, being subdivided into the three transcontinental belts mentioned above, namely, the "Transition," "Upper Austral" and "Lower Austral" zones.

## THE TRANSITION ZONE.

The uppermost of the three Austral divisions is the transcontinental belt in which the Boreal and Austral elements overlap. In Indiana it is represented in the two northern tiers of counties, which counties embrace several hundred fresh water lakes within their bounds. These lakes range in size from an area of half an acre up to five and a half square miles. About their margins are often extensive areas of low boggy land covered with numerous forms of plant life whose main distribution is far to the north and which have here their southern limit. Among the more characteristic plants of the Alleghanian flora, which are found only in the northern fourth of Indiana, are the following: Larch or tamarack, *Larix laricina* (Du Roi); arbor vitae or white cedar, *Thuja occidentalis L.*; false lily of the valley, *Unifolium canadense* (Desf.); moccasin flower, *Cypripedium acaule Ait.*; showy lady's slipper, *Cypripedium reginae* Walt.; bog orchis, *Arethusa bulbosa* L.; fen orchis, *Leptorchis loeselii* (L.); sweet fern, *Comptonia peregrina* (L.); paper or canoe birch, *Betula papyrifera* Marsh; speckled or hoary alder, *Alnus incana* (L.); gold-thread, *Coptis tri-*

*folia* (L.); round-leaved sundew, *Drosera rotundifolia* L.; black chokeberry, *Aronia nigra* (Willd.); round-leaved wintergreen, *Pyrola rotundifolia* L.; shinleaf, *Pyrola elliptica* Nutt.; creeping wintergreen, *Gaultheria procumbens* L.; large cranberry, *Oxycoccus macrocarpus* (Ait.); chickweed wintergreen, *Trientalis americana* Pursh., purple bladderwort, *Utricularia purpurea* Walt., and the twin-flower, *Linnæe borealis* L.

Among the mammals and reptiles the following representatives of the Alleghanian fauna occur in the northern fourth of the State: Canada porcupine, *Erethizon dorsatus* (L.); red squirrel or chickaree, *Sciurus hudsonicus* Erxleben; star-nosed mole, *Condylura cristata* (L.); hoary bat, *Atalapha cinerea* (Beauv.); American badger, *Taxidea americana* (Boddaert); speckled tortoise, *Clemmys guttata* (Schneider); and Blanding's tortoise, *Emys meleagris* Shaw.

Of the Orthoptera from the State, 23 species, or 15.5 per cent of the total, may be classed as belonging to the Alleghanian fauna and as occupying the southern limits of the Transition Zone, which lies between the Boreal and Upper Austral zones. These truly northern members of our Orthopteran fauna are as follows:

INDIANA ORTHOPTERA BELONGING TO THE ALLEGHANIAN FAUNA.

1. *Orphulella pelidna* (Burm.)
2. *Orphulella speciosa* (Scudd.)
3. *Stenobothrus curtipennis* Harr.
4. *Mecostethus lineatus* Scudd.
5. *Camnula pellucida* (Scudd.)
6. *Hippiscus haldemanni* (Scudd.)
7. *Spharagemon wyomingianum* (Thom.)
8. *Trimerotropis maritima* (Harr.)
9. *Schistocerca rubiginosus* (Harr.)
10. *Hesperotettix pratensis* Scudd.
11. *Melanoplus fasciatus* (Walker)
12. *Melanoplus extremus* (Walker)
13. *Melanoplus angustipennis* (Dodge)
14. *Phætaliotes nebrascensis* (Thom.)
15. *Paroxya scudderi* Bl.
16. *Scudderia pistillata* Brunn.
17. *Conocephalus robustus* Scudd.
18. *Orchelimum indianense* Bl.
19. *Orchelimum delicatum* Brun.
20. *Orchelimum gladiator* Brun.
21. *Nemobius paulstris* Bl.
22. *Nemobius confusus* Bl.
23. *Gryllus arenaceus* Bl.

No list of the Coleoptera of the Transition Zone has ever been published, but about 1848 Louis Agassiz and other parties made a trip to the northern shore of Lake Superior, and in a volume published in 1850, treating of the natural history and other features of that region, Dr. J. L. Le Conte listed the beetles taken and described many new species. Of these more than forty have been taken in the northern fourth of Indiana

and nowhere else in the State. They occur for the most part in and around the borders of the Tamarack marshes, which are familiar features in many of the counties in this area of Indiana. Numerous other species whose range is given by Le Conte and Horn as "southern border of British America and northern United States" occur in this Transition Zone of the State, and a complete list of them will be given in the paper on Coleoptera when published.

THE LOWER AUSTRAL ZONE.

The extreme northern boundary of the Lower Austral life zone passes in a northwest-southeast direction through the following counties in Indiana: Vigo, Clay, Owen, Monroe, Jackson, Jennings, Jefferson and Switzerland. In the territory south of this line the Austroriparian fauna of that zone overlaps and merges with the Carolinian fauna of the Upper Austral zone. The extension northward on the western line of the State is, without doubt, due to the presence of the broad and sheltering valley of the Wabash River, within the confines of which certain southern forms have found a climate mild and suitable to their habits. Within this valley the following members of the Austroriparian flora grow indigenously, a number of them as far north as Terre Haute: Bald cypress, *Taxodium distichum* (L.); upright burhead, *Echinodorus cordifolius* (L.); showy amaryllis, *Hymenocallis occidentalis* (LeC.); pecan, *Hicoria pecan* (Marsh); swamp or downy poplar, *Populus heterophylla* L.; chinquapin, *Castanea pumila* (L.); Texan red oak, *Quercus texana* Buckley; pipe vine, *Aristolochia tomentosa* Sims; American lotus, *Nelumbo lutea* (Willd.); Carolina moonseed, *Cebatha carolina* (L.); great burnet, *Sanguisorba canadensis* L.; water or swamp locust, *Gleditsia aquatica* Marsh; water ash, *Fraxinus caroliniana* Mill. and crossvine, *Bignonia crucigera* L.

Among other characteristic southern plant forms occurring in Indiana south of the northern boundary of the Lower Austral zone are: The yellow pine, *Pinus echinata* Mill.; mud plantain, *Heteranthera reniformis* R. & P.; false aloe, *Agave virginica* L.; Spanish oak, *Quercus digitata* (Marsh); southern hackberry, *Celtis mississippiensis* Bosc.; American mistletoe, *Phoradendron flavescens* (Pursh.); cucumber tree, *Magnolia acuminata* L.; pencil flower, *Stylosanthes biflora* (L.); Carolina buckthorn, *Rhamnus caroliniana* Walt.; yellow passion flower, *Passiflora lutea* L.; Hercules club, *Aralia spinosa* L.; persimmon, *Diospyros virginiana* L.; unicorn plant, *Martynia louisiana* Mill.; catalpa, *Catalpa catalpa* (L.), and the rough button-weed, *Diodia teres* Walt.

The southern mocking bird, *Mimus polyglottos* (L.), nests in numbers as far north as Terre Haute, and the "chuckwills widow," a southern ally of the whip-poor-will, occurs in Knox and Gibson counties; while among the batrachians and reptiles the hellbender, *Cryptobranchus alleghaniensis* (Daud.); the southern cricket frog, *Acris gryllus* Le Conte; the corn snake, *Ophibolus doliatus* (L.); Say's chain snake, *Ophibolus calligaster* (Say); the bead snake, *Elaps fulvius* (L.); the ground lizard, *Oligosoma laterale* (Say); the alligator snapping turtle, *Macrochelys lacertina* (Schweigger), and the yellow-bellied terrapin, *Pseudemys troosti* (Holbrook), all forms whose main distribution is far to the south, find in southern Indiana a congenial abiding place.

It is not strange, therefore, that we find living with these plants and animals a number of Orthoptera and Coleoptera whose range has heretofore been thought to be confined to the region mapped by Merriam as the "Lower Austral." Thirty-two of the 148 species of Orthoptera, or 21.6 per cent of the total, may be classed as southern forms. They are as follows:

INDIANA ORTHOPTERA BELONGING TO THE AUSTRORIPARIAN FAUNA.

1. *Temnopteryx deropeltiformis* Brunn.
2. *Ischnoptera inaequalis* Sauss-Zehnt.
3. *Ischnoptera major* (Sauss.-Zehnt.)
4. *Stagmomantis carolina* (L.)
5. *Gonatista grisea* (Fab.)
6. *Anisomorpha ferruginea* (Pal. de Beauv.)
7. *Tettix arenosus* Burm.
8. *Neotettix hancocki* Bl.
9. *Tettigidea spicata* Morse.
10. *Tettigidea lateralis* (Say).
11. *Syrbula admirabilis* (Uhl.)
12. *Hippiscus phœnicopterus* (Germ.)
13. *Mestobregma cinctum* (Thom.)
14. *Trimerotropis citrina* Scudd.
15. *Leptysma marginicollis* (Serv.)
16. *Schistocerca damnifica* (Sauss.)
17. *Melanoplus morsei* Bl.
18. *Melanoplus impudicus* Scudd.
19. *Amblycorypha uhleri* (Brunn.)
20. *Conocephalus bruneri* Bl.
21. *Atlanticus dorsalis* (Burm.)
22. *Camptonotus carolinensis* (Gers.)
23. *Ceuthophilus stygius* (Scudd.)
24. *Ceuthophilus uhleri* Scudd.
25. *Myrmecophila pergandei* Brun.
26. *Nemobius canus* Scudd.
27. *Nemobius cubensis* Sauss.
28. *Gryllus firmus* Scudd.
29. *Miogryllus saussurei* (Scudd.)
30. *Phylloscirtus pulchellus* (Uhl.)
31. *Apithes agitator* Uhl.
32. *Orocharis saltator* Uhl.

Of the species listed but four, one of them being the Carolina mantis or rear-horse, *Stagmomantis carolina* (L.), and the others *Camptonotus carolinensis* (Gers.), *Syrbula admirabilis* (Uhl.) and *Orocharis saltator* Uhl., have been taken in small numbers as far north as Marion County; all of the others only south of the line mentioned as forming the northern border of the Lower Austral.

In this Lower Austral zone I have also taken more than one hundred species of beetles whose range heretofore has been given as the Gulf or Southern States. Among them are some of the largest and most striking members of Coleoptera taken within the State, regular "Oh, my! beetles;" that is, those which beget the ejaculation "Oh, my!" when they are noted by persons not especially interested in the order. Among these two of our largest tiger beetles of the genus *Tetracha;* the stag beetle, *Lucanus elaphus* Fab.; the rhinoceros beetle, *Dynastes tityrus* Linn.; the unicorn beetle, *Xyloryctes satyrus* Fab., and the fig-eating beetle, *Allorhina nitida* L., are examples most worthy of note.

It will be noted that the line which separates the Lower Austral from the Upper Austral zones in the State corresponds somewhat approximately with the southern border of the glacial invasion of Indiana, and it is more than probable that the ancestors of many of these southern forms existed in southern Indiana in preglacial times, when the climate was much warmer than now. It is also probable that many of these Orthoptera and Coleoptera, as well as a number of those species inhabiting the entire State, advanced into the State from the south as fast as it was uncovered by the receding ice.

## UPPER AUSTRAL ZONE.

Of the Upper Austral Zone, which covers the greater portion of the State and whose fauna and flora overlap and merge with those of the Transition Zone in the north and the Lower Austral Zone in the south, I have but little to say, as this fauna and flora are the ones whose members are most familiar to all present. Merriam, in his paper above cited, states that counting from the north, the Upper Austral area, represented by the Carolinian fauna and flora, is that in which the sassafras, tulip tree, hackberry, sycamore, sweet gum, redbud and short leafed pine first make their appearance. Along with these trees and shrubs are found the opossum, gray fox, fox squirrel, cardinal, Carolina wren, tufted titmouse, blue-gray gnatcatcher, summer tanager and yellow-breasted chat.

As already mentioned, the great proportion of the Orthoptera and Coleoptera of the State belong to this Carolinian fauna, and a great majority of the same species are found in Ohio, the eastern two-thirds of Kentucky, nearly all of Illinois, Iowa and Missouri and the eastern halves of Nebraska and Kansas.

To the facts above given many others could doubtless be added by those members of the Academy from the extreme northern or southern portions of the State who have studied rather closely the fauna and flora of their respective areas.

# Animals of the Olympic Peninsula, Washington.[1]

By Albert B. Reagan.

For the past three years I have been making observations on the animals of the Olympic Peninsula as time would permit. These I give below:

*Sciurus douglasi* Bach.

This is a very common squirrel. It is colored grizzly rufus to rusty; but in color its tail is very variable. It lives in the coniferous forest and feeds upon the cones.

*Tamias townsendi* Bach. Washington Chipmunk.

A very pretty chipmunk found everywhere to an elevation of 2,000 to 4,000 feet. I saw one specimen at snow line at the head of the Soleduck River.

From the shore line to the snow-capped mountains these squirrels were observed to bark when suddenly disturbed; but when calling each other they uttered a querulous chirp. This squirrel is very shy till it gets "acquainted." Then it becomes quite a pest and a little thief. At the Soleduck springs I have seen them crawl over a person while lying still, and have known them to steal bread off of a table in the same tent where cooking was going on.

*Tamias caurinus* Merr.

Only one individual of this species was seen at timber line in the Happy Lake country.

*Arctomys olympicus* Merr. Olympic Marmot.

I saw only one pair of these animals on a ridge between the Soleduck River and East Fork. Their color was ochraceous yellow. In actions they imitate a prairie dog very much; but in size they are considerably larger. Some are said to weigh as much as twenty-five pounds.

1. In identifying the species here given I have used the "Catalogue of Mammals from the Olympic Mountains, Washington," by D. G. Elliot ("Field Columbian Museum Publication 32"), and Jordan's "Manual of Vertebrates," as reference books.

RAILROADS OF THE OLYMPICS


LINES IN OPERATION. RAILROAD EXTENSIONS TO BE MADE IN THE NEAR FUTURE.

*Sciuropterus alpinus olympicus* Elliot. Olympic Flying Squirrel.

One individual of this species was caught in a trap at La Push by one John Sailto last winter while trapping for mink. This is the only one seen in the region so far as the writer knows. The animal is supposed to be nocturnal in its habits.

*Hoplodontia olympica* Merr. Olympic Mountain Beaver or "Gehalis Farmer."

I have seen several hides of these animals which the Indians had procured to sell to the fur companies; also some captured young. But I have never visited their farms. The natives tell me that these little animals cut down a grass or low lily near where they make their burrows, spread out the hay and dry it in the sun and then take it into their holes to serve as food or bed. These beavers are much smaller than the beavers of the Mogollon Mountains, the only other beavers I have seen.

*Peromyscus akeleyi* Elliot.

This long-tailed, large-eared mouse is a common pest and is to be found everywhere. It rivals the domestic mouse of the Eastern States in its efforts to live in the same house with the master of creation when a cabin is pitched in the forest. But it is more easily caught than its brother mouse; 54 were drowned in a waterpail in a house on the edge of a new clearing near here in one night. In color it is rather dark with an almost black dorsal area. And in size it is a little under that of the domestic mouse. Its tail is as long or longer than the head and body.

*Neotoma occidentalis* Baird. Wood Rat.

A colony of these rats was found at the mouth of the Hoh River. I went to stay all night in a house where a bachelor was staying. The owner said the house was haunted, that the former owner was a sea captain, and that, wrecking his ship on the reefs at the mouth of the river adjacent, his troubled spirit came back at night and thumped and knocked about the floors and house walls. I said nothing but set a "figure four" trap; and the next morning it was not the sailor's spirit that was in it, but instead there was a huge wood rat.

In color this rat resembles *Neotoma cinerea columbiana* very much but is darker, especially along the dorsal area. It has a conspicuous bushy tail. The animal has some very peculiar habits. It carries large sticks of wood around, and when on a floor or anything which will produce a sound it thumps the wood up and down on the sounder for no other purpose, it seems, than that of hearing the noise. It makes its nest of

sticks. Another peculiar characteristic it has is that of "trading;" it never takes anything without leaving something in its place. For this reason it is called the "trade rat" by the settlers. In size it is about as large as a common gray squirrel.

*Evotomys nivarius* Bailey.

This alpine species of mouse was seen only near the Happy Lake country. It lives in colonies. In color its dorsal surface is strongly marked with chestnut, sides of body gray and buff, under parts white, tail bi-color. The tail is half as long as the body.

*Microtus macrurus* Merr.

I found a dead specimen on the trail from Crescent Lake to the Soleduck Hot Springs. It seems to be rare.

*Microtus morosus* Elliot.

A common species.

*Microtus oregoni* Bach. Meadow Vole.

Not many individuals of this species were seen by the writer.

*Thomomys melanops* Merr. Gopher.

This animal is a common pest in hay fields. In color it is pale brown to reddish, with considerable black about the head and face.

*Zapus imperator* Elliot. Kangaroo Mouse.

This is an abundant species, but hard to catch. In color its sides are buff, back dark, under parts white.

*Sorex vagrans* Baird. Shrew.

Only three individuals of this species were seen.

*Lepus washingtoni* Baird. Washington Rabbit.

Description: Male—Brown from head to tail on back and sides. Chin and lower jaw white to light brown, neck brown beneath, rest of under parts white, legs brown without, front legs white on outside, front of hind legs white, hair reddish brown on flanks just in front of each hind leg, tip of toes of each foot white. Tail short, ending in a tuft of dark hair, color of hair above dark brown, light brown beneath. Anal tuft nearly white. Hind legs from knee to foot on back dark to dark brown. Each front leg has a small linear white spot on front of knee.

Length of head 3.125 in., thickness of head at base of skull 2.625 in., width of base of lower jaw 1.875 in., width of ear at widest part 1.375 in., length of middle front toe 1 in., length of hind leg 11.125 in., length of hind foot and leg beneath the knee 4.875 in., length of hind foot 1.875 in., length

of middle toe of hind foot 1.375 in., length of claw of middle toe of hind foot .5 in., length of neck 2 in., length of body 11 in., length of tail 1.125 in.

Female—The sides of the female are a lighter brown than those of the male and the white of the lower parts have longer hairs of brown scattered through them in numbers enough to make those parts appear light brown. The female is considerably larger than the male.

Both the male and female rabbits walk more on the hind leg from the knee down to the foot than the "cotton tail" does. These rabbits are quite numerous.

*Cervus canadensis occidentalis* H. Smith (*C. roosevelti* Merr.) Roosevelt Elk.

Description: Head, neck, legs, rump black to brown.

This animal is now found principally above three thousand feet elevation. They are not plentiful. I saw seventeen near the Soleduck Hot Springs in August, 1906.

*Odocoileus* (*Cervus*) *herminous* Rafin. Black-tailed Deer.

This deer is found principally in the "Frozen Lake" country up near the Olympics proper. It is not plentiful.

*Felis rufa fasciata* Elliot (Raf.).

This animal is large and savage. It is due to the ravages of this animal that the deer and elk have been so reduced in numbers. In color it is a rich chestnut to a mahogany red.

*Canis latrans* Say. Coyote.

Two of these animals were killed by one of the forest rangers last year. They evidently were strays.

*Canis nubilus* Say. Gray Wolf.

These animals are now practically extinct; the settlers killed them by wholesale with poison to keep them from making raids on their sheep ranches.

*Ursus americanus* Pall. Black Bear.

This is a very common animal. It lives principally on berries in the fall of the year. The principal berries it eats are salal, salmon, red elder, thimble, huckleberries and blueberries. It gets fat on berries and is then good eating. In the spring it lives principally on skunk cabbage. It digs it up and eats it root and all. But when the salmon begin to "run" the bear leaves his cabbage garden and his berry patch and turns fisher-

man. And he catches the fish, too. He goes to a ripple and wades out into the water and waits for a fifty pounder to come along, and then he seizes it with his front paws and teeth and drags it ashore. At other times he gets on a log over the stream or on the bank and when the vanguard of the salmon army comes along on its march to the upper tributaries he springs into the water and seizes one of their number; and he seldom misses his aim.

*Mustela pennanti pacifica* Rhoads. The Fisher.

This animal is about the same size as the eastern fisher. Its fur is long, thick and glossy, varying from a jet black to a grizzly gray, especially on the head and neck. The tail is long and bushy. This animal is rare.

*Mustela americana* Kerr. Pine Marten.

In color this animal is brown and not darker below than above, with tawny throat patch. The ears are high and sub-triangular. I have seen but a few of these animals. They seem to be rare.

*Putorius vison energuminus* Bangs. Mink.

This animal is large and the usual mink color. Some specimens, however, have chin, center of throat and anal regions white, with a few scattering white hairs upon the breast.

*Putorius washingtoni* Merr.

Only two individuals of this species were seen at the head of the Soleduck River.

*Putorius streatori* Merr.

This is a very common weasel. It has a somewhat variable color, with a black spot thrown in now and then.

*Lutra canadensis* Schreber. American Otter.

These animals are frequently trapped by the Indians. Their skins sell for $25 or more each.

*Mephitis foetulenta* Elliot.

This is a very common skunk. It is met with principally along the beach, where it feeds on seaweed and shellfish. A dozen of them have been seen on the beach in an hour's walk. They come out usually just before dusk, though an occasional one may be seen at any hour of the day. They are not the least bit shy, as a rule, and are not troublesome unless attacked.

*Spilogale olympica* Elliot.

This is a very common striped skunk. The Indians catch them for their skins; also for the skunk oil, which they use as medicine.

*Scapanus townsendi* Bach. Mole.

In color this animal is black with a silvery gloss; its feet are human skin color.

A stuffed specimen is now in the museum of the Kansas Academy of Science.

*Myotis yumanensis saturatus* Miller. Yellowish-Brown Bat.

This species is quite numerous.

*Procyon lotor* L. Raccoon.

This animal is very common.

*Enhydris (lutris?) marina.* Sea Otter.[1]

This animal is not common; but it is occasionally captured or found dead on the beach.

A starving aged squaw found one on the beach near here some four years ago while looking for barnacles to eat. She put it in her basket and brought it home, skinned it and sold the pelt for more than $200; then gave a "potlatch" with the money and starved to death herself the next summer.

*Eumetopias ateleri.* Sea Lion.[1]

These animals inhabit the jagged island group between Ozette and La Push. I have visited the islands twice, and each time have had the luck to see hundreds of these animals basking in the sun on the rocks, hear their bellowing and see their playing. It is quite amusing to see a sea lion "scratch" himself with his flippers. The Indians kill the sea lion for its flesh, which they relish very much.

*Phoca vitulina.* Hair Seal.[1]

These seals inhabit the rocky islands of the whole coast. The Indians kill them for their flesh and also for their hides. The skins are removed as near whole as possible, turned hair side in, tied up so as to be airtight, then inflated. They are then used as buoys in catching whale. No other wild animal is so useful to the Quilentes.

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The last three species are sea animals and are classed here only for convenience

# The Circulation of Mixed Blood in the Embryo Mammal and Bird, and in the Adult Reptile, Amphibian and Fish.

By A. G. Pohlman.

Our conception of the course of the blood through the heart of the lower vertebrates appears to be based almost entirely on the conditions found in the adult of the warm-blooded forms (birds and mammals). It is well known that the adult bird and mammal possess a double circulation, i. e., a cycle in which venous blood is propelled from the heart to be returned oxygenated (pulmonary circulation), and one in which arterial blood is expelled to be returned venous (systemic circulation). The afferent and efferent vessels are in no way connected save through a capillary system, and for this reason the heart may be divided into a right or venous and a left or arterial heart. While the greater part of the seventeenth century was occupied with the Harvey doctrine, the eighteenth century found men equally engaged with the course of the blood through the fetal heart. Three distinct theories were suggested before the beginning of the nineteenth century—one based on alleged physiological necessity, a second on the anatomical relations found in the fetal mammalian heart, and a third on the logical deductions from the differences between the fetal and adult circulatory conditions. The differences between the fetal and adult heart in mammals are, briefly, the right auricle receives the precavals (venous) and the post-caval vein (V. cava inf.), which is arterial; a communication between the right and left auricle is present (foramen ovale), and a connection is found between the heart efferents (pulmonary artery and aorta) in the ductus arteriosus.

The theory based on physiological necessity (von Haller-Sabatier) was this: if the left heart in the adult is arterial, then the chances are it must also be arterial in the fetus; hence the oxygenated blood in the post-caval vein must pass through the foramen ovale into the left heart. It was further inferred that because the ductus arteriosus short-cut the venous blood from the pulmonary artery into the descending aorta, the vessels arising from the aortic arch would convey a better quality of blood.

The net result of this scheme was that not only did the head and upper extremities receive a better quality of blood, but a right venous and a left arterial heart was maintained and a function was suggested for the Eustachian valve in the right auricle. Unfortunately this doctrine has been antagonized since 1835 with little effect on the described circulation in the mammalian fetus, and with no consideration of its evident defects in the latest text-book (3) on chick embryology. At the last meeting of the Academy I labeled the scheme "morphologically inaccurate, developmentally unnecessary and physically impossible." The second theory (Wolff) was based on excellent anatomical observation but does not fulfil the physical requirements of the proposition. The third theory (Harvey), a mixing of the blood in the right auricle, was quite definitely demonstrated to occur in the living fetal pig. I found by injection experiments that the blood passing into the heart from the right precaval and the postcaval veins found its way into both ventricles. Interpreted in a physiological manner, the result is that all the arteries in the mammalian embryo contain a mixed blood. The point raised, while of no practical importance in itself, is interesting because it was first suggested by Harvey in 1628; because it may lead to a more perfect understanding of the anatomical changes from the fetal to the adult circulation; and lastly because of its morphological significance. It is the latter point that I would bring out in greater detail.

It is well known that the double circulation is found only in the warm-blooded adult vertebrates (bird and mammal); animals in other words, where the body temperature demands a greater degree of oxygenation and in which the oxygenation is entirely confined to the lungs. In the lower vertebrates this condition does not obtain, reptiles excepted. The amphibian has other means of obtaining oxygen than through the lungs, and the fish, other paths than through the gills. The relatively low body temperature does not necessitate so rich a content of oxygen in the blood. If we examine this statement closely we see that the embryos of mammal and bird resemble the reptile and amphibian; they do not possess a distinct four-chambered heart, and while in the latter the element of warmth does not enter, in the former the warmth, practically speaking, is supplied by the maternal body through internal or external incubation. The metabolic processes of the mammal and bird are therefore insufficient to maintain the essential body temperature.

If we examine the phylogenetic relation of the mammal and bird we

note that the higher mammals carry the offspring to term; the marsupials have a short period of gestation, and while the young are born in a very immature condition, they are brooded in a sac (marsupium); the monotreme's method does not differ essentially from that of the bird save perhaps in the mode of the incubation of the egg and the postembryonal care of the offspring. It would therefore be a logical inference to grant that the circulatory conditions in the fetal mammal and bird were about the same. Indeed the von Haller-Sabatier theory has been carried over directly to the bird, i. e., the right heart of the fetal bird is described as venous, the left as arterial.

I have stated that the latest text-book on chick embryology translates this blood segregation theory from mammal to bird with no comment on its defects. If the postcaval vein in the chick does carry the arterial blood richly laden with nourishment from the yolk to the left auricle through the foramen ovale, then the relations of the precaval to the postcaval openings must be vastly different from what they are in the mammal —but they are not. Further, if this is a developmental necessity, what is the character of the circulation in the anomalies where the right precaval opens with or into the postcaval? Is it possible for the described conditions to obtain in these cases or in Rhea americana, where, according to Gasch (2), the common opening of the right precaval and the post caval is the normal. I have no experimental evidence to bring up as yet for the mixing of the blood in the right auricle of the bird, but I believe there is sufficient ground for the claim that it occurs from the similarity to the mammal in heart structure, developmental requirements, and from the aberrant types such as I have mentioned.

Phylogenetically the connecting link between bird and reptile is particularly strong; ontogenetically the requirements for development differ only in body temperature (viviparous forms excluded), and we would therefore expect little difference in the character of blood circulation, although the heart structure is quite different. Taking the turtle as the type, the described circulation is about as follows: the right auricle is venous, the left auricle arterial—both open into the incompletely divided ventricle by separate openings. The blood from these two sources is segregated in corresponding parts of the ventricle, and when the ventricle contracts, the incomplete septum touches the ventricular wall, isolating a part of the venous blood in a sort of right chamber of the ventricle. The venous blood is expelled through the pulmonary artery, mixed blood is

sent out through the right aorta, while the left aorta is purely arterial. This is again the same scheme as we found in the mammal and results in the head receiving a better quality of blood.

Experiments were performed on three species of turtles to ascertain if this condition prevailed. The plastron removed and the heart laid bare, a double ligature was passed through the transverse pericardial sinus and arranged to tie one at the distal, the other at the proximal edge of the sinus. Next cornstarch granules suspended in normal salt solution were introduced into the auricles during diastole; the auricle allowed to contract, giving time to have the distal ligature ready to tie off; the distal ligature was tightened during ventricular systole and immediately the proximal one—isolating three columns of blood in the three vessels. These were bled separately into watch glasses containing dilute acetic acid and examined for the granules. It was found that granules injected into the right and left, and in both auricles simultaneously, were always recovered from all three efferent vessels. It must also be remembered that in the turtle the fetal circulation is not unlike that found in the fetal bird—the postcaval vein conveys the oxygenated blood, and if this segregation of blood occurred as described in the adult, the head would receive only venous blood. This objection also holds good in the Crocodilia, where, according to Wiedersheim (6), the condition is as follows: "The blood from the right ventricle passes into the pulmonary artery as well as into the left aortic arch and, according as the septum ventriculorum is complete or incomplete, is either entirely venous (Crocodilia) or mixed (other reptiles). A complete septum ventriculorum thus appears for the first time in crocodiles, in which, consequently, the right ventricle contains unmixed venous blood and the left ventricle unmixed oxygenated blood, although, as will be seen presently, an admixture takes place in the systemic arteries." Again, according to this scheme, the head will receive a better quality of blood because the carotids arise from the left aortic arch, but again the objection as to the manner of transformation from the fetal crocodile to the adult crocodile heart would arise. This form certainly needs careful investigation. The purely venous blood would far exceed the purely arterial, and the mixture at the foramen of Panizza might be very complete.

The amphibian circulation is naturally described on the basis of the segregation of blood and must therefore fall into two classes, the anural and the urodele. The description of the anural circulation is delightfully

exact and comprehensive and is as follows: "It will be perceived that the blood poured into the right auricle is mostly impure or venous, that poured into the left fully aerated or arterial. When the auricles contract, which they do simultaneously, each passes its blood into the corresponding part of the ventricle, which then *instantly* contracts before the venous and arterial bloods *have time to mix*. Since the conus arteriosus springs from the right side of the ventricle, it will at first receive only venous blood, which, on contraction of the conus, might pass either into the bulbus aortae or into the aperture of the pulmo-cutaneous trunks. But the carotid and systemic trunks are connected with a much more extensive capillary system than the pulmo-cutaneous, and the pressure in them is proportionately great, so that it is easier for the blood to enter the pulmo-cutaneous trunks than to force aside the valves between the conus and bulbus. A fraction of a second is, however, enough to get up the pressure in the pulmonary and cutaneous arteries, and in the meantime the pressure in the arteries of the head, trunk, etc., is constantly diminishing owing to the continual flow of the blood toward the capillaries (sic). *Very soon*, therefore, the blood forces the valves aside and makes its way into the bulbus aortae. Here again the course taken is that of least resistance; owing to the presence of the carotid gland the passage of blood into the carotid trunks is less free than into the wide elastic systemic trunks. These will therefore receive the next portion of blood, which, the venous blood having mostly been driven to the lungs, will be a mixture of venous and arterial. Finally, as the pressure rises in the systemic trunks, the last portion of blood from the ventricle, which, coming from the left side, is arterial, will pass into the carotids and so supply the head."

It will be seen on critical examination of this scheme that several points are open to argument even if we grant the segregation of bloods in the spongy ventricle: 1, the element of time; 2, the mechanics; 3, the comparative anatomy; and 4th, the experimental evidence. 1. The frog's heart under normal conditions beats about 60 to the minute with a ventricular systolic phase of about 0.2 sec. Now if one reads the description, bearing in mind that the whole process is completed in one-fifth of a second, and that all this is inferred in order that the head shall receive a better blood supply, one is tempted to hold one's breath. The time is short and much must be accomplished. If the blood in the systemic arteries is being forced toward the capillaries, what is holding it back in the pulmo-cutaneous and carotid trunks? Again the regulation of the valves and re-

sistance to the flow of blood must indeed be very minutely adjusted to separate the venous from a mixed and a mixed from an arterial blood issuing from the same opening with say, one-fifteenth of a second to accomplish each phase. 2. Further the tracings made by Gompertz show that the blood reaches the pulmo-cutaneous and aortic trunks at the same time and under the same pressure. Still further the inspiration in the frog increases, not decreases, the intrathoracic pressure and would retard the pulmo-cutaneous system, and it has not been demonstrated satisfactorily to my knowledge that the capillary system of the pulmo-cutaneous vessels is actually less developed than in the systemic area. 3. The comparison of the various types of amphibian circulation is of interest. Bruner (1), for example, makes the following statement: "The fact that the septum atriorum disappears with the lungs indicates clearly that in the salamanders with lungs the septum performs a certain function which becomes superfluous or impossible after the loss of these organs. This function is the separation of the venous blood of the right auricle from the aerated blood of the left auricle. But what is the significance of this separation if the two sorts of blood are afterward mixed during the passage through the ventricle and conus? Or is there, after all, in salamanders with lungs a partial separation of the aerated and the venous blood in its entire course through the heart? Such a separation occurs, as is well known, in the heart of Rana. Now as regards the atrium and ventricle, we find essentially the same structure in Salamandra as in Rana. It is true that the septum atriorum in the salamander is perforated, while in the frog it is not. But during the brief stay of the blood in the auricles the small perforations which have been described would permit little mixing of the blood. There would be much better opportunity for this to occur in the ventricle, but here we have the same spongy condition in Salamandra and Rana. So far then, Rana does not seem to have a decided advantage over the salamander in respect to the separation of venous and arterial blood in the heart. We may therefore conclude that in the salamander, as in Rana, the first blood passing from the ventricle into the conus during the ventricular systole is chiefly venous. In Rana this is directed into the pulmonary artery. In the salamander, however, the structure of the conus does not indicate that it could influence the direction of the blood current. We must turn, then, to the bulbus arteriosus and the great arterial vessels for further light on our problem." "The spiral valve of the salamanders can have no control over the direction of blood which passes

through the conus." Preceding this Bruner states: "The conus of the Salamandrina shows the same general structure as that we found in the conus of the Salamandra. A spiral valve is distinctly recognizable in the lungless form." (Salamandra has lungs; Salamandrina has none.)

This point in the comparative anatomy of the amphibian circulation I hold to be an excellent objection to the described course of the blood through the frog heart.

4. Experimental evidence on the amphibian circulation leaves much still to be done. Mayer found that if the tip of the ventricle was cut off the blood issued in two distinct streams. This, in addition to the coloration in the beating frog heart, seems to hold for a segregation of the venous and arterial blood in the spongy ventricle. But Gompertz's experiments also seem to indicate that even if this be true a mixing must occur in the vessels.

The step from the amphibian to the class of Dipnoi is not a very great one, and still we find something which may throw light on the character of blood circulating in the fish. According to Wiedersheim "in Ceratodus the conus arteriosus is provided with eight rows of valves and begins to be divided into two chambers. In Protopterus this division is complete, so that two currents of blood, mainly arterial and mainly venous respectively, pass out from the heart side by side. The former comes from the pulmonary vein, from which it passes into the left atrium, thence into the left portion of the ventricle, and thence to the two anterior branchial arteries. The venous current, on the other hand, passes from the right portion of the ventricle into the third and fourth afferent branchial arteries and thence to the corresponding gills, where it becomes purified; it reaches the aortic roots by means of the efferent branchial arteries. The paired pulmonary artery, like the corresponding vessel in the crossopterygians, arises from the fourth efferent branchial in Ceratodus, and from the aortic root in Protopterus and Lepidosiren."

There appears to be a physiological flaw in this description unless the fish blood behaves quite differently from that in other animals. Under the assumption that the blood in the fish becomes fully oxygenated in its passage through the gills, the blood carried to the lungs from the efferent branchial artery would already be charged with oxygen, and in this case the lungs would only be functional when the fish is hibernating in the dried mud. Under the assumption that the fish blood is not fully oxygenated in its passage through the gills, the lungs would be accessory to

the gill function. In neither case would there be any physiological reason for the separation of the blood issuing from the conus. If the gills in the fish do not entirely oxygenate the blood, and in some fish the fins apparently assist in oxygenation, then the fish blood really corresponds to our notion of "the mixed blood" (not fully oxygenated) in the higher forms. Here again is a problem upon which no definite information may be given.

In conclusion, my position on the quality of blood circulating in the arteries of the vertebrates is that it is what may be termed "mixed" in all forms from the embryo mammal and bird to the fish, and if there have been advanced various theories on the mechanics of the passage of the blood through the heart of a given form they have been based on the alleged physiological necessity for a better quality of blood circulation in the head. In other words the systemic arteries convey arterial blood only in the mammal and bird after birth. I believe if one eliminates the idea that the head must receive a better quality of blood (Sabatier scheme) the whole doctrine of the character of the circulation in all forms of vertebrates is not only simplified but placed upon a sound physiological and developmental basis.

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# The Indiana Academy of Science.

By J. T. Scovell.

Professional men engaged in almost every kind of scientific work united to form the Indiana Academy of Science.

These people hoped to be benefited by the Association; they believed that it would promote scientific research and aid in the diffusion of knowledge concerning scientific affairs. The people who formed the Academy and aided in its development hoped that as the years rolled by it would so stimulate and encourage scientific work as to make it an important adjunct to the educational system of the State.

From the first, in addition to professional work, it has been the policy to encourage students and amateurs to prepare papers which in effect are reports of work done along some line of scientific investigation. The work may be new to science or it may not, but is new to the writer. The student gets the benefit of the work done and of the friendly criticism of the Academy.

Many valuable papers have been prepared on many different phases of scientific work. Considerable work has been done by the Academy on the flora of the State. Some of the best work that has been done on the botany of the State has been done by members of the Academy. The conservation of forests the study of streams and of climate and all sorts of geological questions have been discussed in the Academy. There have been reports on the reptiles of the State and on the fish that abound in the streams. And several papers have been presented on the insects of the State. One could not discuss any of these subjects fully without consulting the reports of the Academy. Several papers that were presented to the Academy appear in a Geographical Study of Indiana, and several Academy papers appear in the geological reports of Indiana.

Similar work has been done in Chemistry, Physics, Mechanics, Mathematics and in other subjects.

The Academy affords an opportunity for social converse among scientific men, for exchange of ideas and the stimulus of association.

It is in some sense a laboratory where students are stimulated to work, the work in many cases counting as credits on university work. Again these reports are printed, and so this work becomes accessible to many outside the members of the Academy. Again, the Academy has established an extensive system of exchanges of publications with other societies, so that a large number of valuable publications are accumulated in the State Library to the credit of the Academy.

Various sanitary problems have been discussed and some phases of bacteriology and some economic questions have been considered: as to the supply of coal, of building stones and of materials for all kinds of articles made of clay or shale.

The list of presidents contains the names of many noted men who have done good work in the Academy. And the list of members is large, showing that hundreds of people have been inspired and stimulated by association with these prominent educators. A large proportion of the members of the Academy are teachers, and through them thousands of young people in Indiana have been benefited and encouraged by the work of the Academy.

The Indiana Academy of Science has been a success. It has accomplished in a large way all that its founders hoped for. May it continue to prosper.

# INDEX.

# PROCEEDINGS

OF THE

# Indiana Academy of Science

TWENTY-FIFTH ANNIVERSARY

1909

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EDITOR . . . . . . . . . . . . . H. L. BRUNER

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INDIANAPOLIS, IND.
1910

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1910

THE STATE OF INDIANA,
EXECUTIVE DEPARTMENT,
January 17, 1910.

Received by the Governor, examined and referred to the Auditor of State for verification of the financial statement.

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OFFICE OF AUDITOR OF STATE,
INDIANAPOLIS, Feb. 7, 1910.

The within report, so far as the same relates to moneys drawn from the State Treasury, has been examined and found correct.

J. C. BILLHEIMER,
*Auditor of State.*

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February 8, 1910.

Returned by the Auditor of State, with above certificate, and transmitted to Secretary of State for publication, upon the order of the Board of Commissioners of Public Printing and Binding.

MARK THISTLETHWAITE,
*Secretary to the Governor.*

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Filed in the office of the Secretary of State of the State of Indiana, February 8, 1910.

FRED A. SIMS,
*Secretary of State.*

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Received the within report and delivered to the printer February 9, 1910.

A. E. BUTLER,
*Clerk Printing Board.*

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## AN ACT TO PROVIDE FOR THE PUBLICATION OF THE REPORTS AND PAPERS OF THE INDIANA ACADEMY OF SCIENCE.

[Approved March 11, 1895.]

Preamble.

WHEREAS, The Indiana Academy of Science, a chartered scientific association, has embodied in its constitution a provision that it will, upon the request of the Governor, or of the several departments of the State government, through the Governor, and through its council as an advisory body, assist in the direction and execution of any investigation within its province, without pecuniary gain to the Academy, provided only that the necessary expenses of such investigation are borne by the State; and,

WHEREAS, The reports of the meetings of said Academy, with the several papers read before it, have very great educational, industrial and economic value, and should be preserved in permanent form; and

WHEREAS, The Constitution of the State makes it the duty of the General Assembly to encourage by all suitable means intellectual, scientific and agricultural improvement; therefore,

Publication of the Reports of the Indiana Academy of Science.

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana*, That hereafter the annual reports of the meetings of the Indiana Academy of Science, beginning with the report for the year 1894, including all papers of scientific or economic value, presented at such meetings, after they shall have been edited and prepared for publication as hereinafter provided shall be published by and under the direction of the Commissioners of Public Printing and Binding.

Editing Reports.

SEC. 2. Said reports shall be edited and prepared for publication without expense to the State, by a corps of editors to be selected and appointed by the Indiana Academy of Science, who shall not, by reason of such service, have any claim against the State for compensation. The form, style of binding, paper, typography and manner and extent of illustration of such reports shall be determined by the editors, subject to the approval of the Commissioners of Public Printing and Stationery.

Number of Printed Reports.

Not less than 1,500 nor more than 3,000 copies of each of said reports shall be published, the size of the edition within said limits to be determined by

the concurrent action of the editors and the Commissioners of Public Printing and Stationery: *Provided*, That not to exceed six hundred dollars ($600) shall be expended for such publication in any one year, and not to extend beyond 1896: *Provided*, That no sums shall be deemed to be appropriated for the year 1894.

**Proviso.**

SEC. 3. All except three hundred copies of each volume of said reports shall be placed in the custody of the State Librarian, who shall furnish one copy thereof to each public library in the State, one copy to each university, college or normal school in the State, one copy to each high school in the State having a library, which shall make application therefor, and one copy to such other institutions, societies or persons as may be designated by the Academy through its editors or its council. The remaining three hundred copies shall be turned over to the Academy to be disposed of as it may determine. In order to provide for the preservation of the same it shall be the duty of the Custodian of the State House to provide and place at the disposal of the Academy one of the unoccupied rooms of the State House, to be designated as the office of the Indiana Academy of Science, wherein said copies of said reports belonging to the Academy, together with the original manuscripts, drawings, etc., thereof can be safely kept, and he shall also equip the same with the necessary shelving and furniture.

**Disposition of Reports.**

SEC. 4. An emergency is hereby declared to exist for the immediate taking effect of this act, and it shall therefore take effect and be in force from and after its passage.

**Emergency.**

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## APPROPRIATION FOR 1910-1911.

The appropriation for the publication of the proceedings of the Academy during the years 1910 and 1911 was increased by the legislature in the General Appropriation bill, approved March 9, 1909. That portion of the law fixing the amount of the appropriation for the Academy is herewith given in full:

For the Academy of Science: For the printing of the proceedings of the Indiana Academy of Science, twelve hundred dollars: *Provided*, That any unexpended balance in 1909 shall be available in 1910, and that any unexpended balance in 1910 shall be available in 1911.

**Academy of Science—Regular.**

## AN ACT FOR THE PROTECTION OF BIRDS, THEIR NESTS AND EGGS.

SEC. 602. Whoever kills, traps or has in his possession any wild bird, or whoever sells or offers the same for sale, or whoever destroys the nest or eggs of any wild bird, shall be deemed guilty of a misdemeanor and upon conviction thereof shall be fined not less than ten dollars nor more than twenty-five dollars: *Provided*, That the provisions of this section shall not apply to the following named game birds: The Anatidae, commonly called swans, geese, brant, river and sea duck; the Rallidae, commonly called rails, coots, mud-hens, gallinules; the Limicolae, commonly called shore birds, surf birds, plover, snipe, woodcock, sandpipers, tattlers and curlew; the Gallinae, commonly called wild turkeys, grouse, prairie chickens, quails and pheasants; nor to English or European house sparrows, crows, hawks or other birds of prey. Nor shall this section apply to persons taking birds, their nests or eggs, for scientific purposes, under permit, as provided in the next section.

SEC. 603. Permits may be granted by the Commissioner of Fisheries and Game to any properly accredited person, permitting the holder thereof to collect birds, their nests or eggs for strictly scientific purposes. In order to obtain such permit the applicant for the same must present to such Commissioner written testimonials from two well-known scientific men certifying to the good character and fitness of such applicant to be entrusted with such privilege, and pay to such Commissioner one dollar therefor and file with him a properly executed bond in the sum of two hundred dollars, payable to the State of Indiana, conditioned that he will obey the terms of such permit, and signed by at least two responsible citizens of the state as sureties. The bond may be forfeited, and the permit revoked upon proof to the satisfaction of such Commissioner that the holder of such permit has killed any bird or taken the nest or eggs of any bird for any other purpose than that named in this section.

# Indiana Academy of Science.

## OFFICERS, 1909–1910.

PRESIDENT

P. N. Evans.

VICE-PRESIDENT

C. R. Dryer.

SECRETARY

Geo. W. Benton.

ASSISTANT SECRETARY

A. J. Bigney.

PRESS SECRETARY

John W. Woodhams.

TREASURER

W. J. Moenkhaus.

EXECUTIVE COMMITTEE

P. N. Evans,
C. R. Dryer,
G. W. Benton,
A. J. Bigney,
J. W. Woodhams,
W. J. Moenkhaus,
A. L. Foley,
Glenn Culbertson,
D. M. Mottier,
Robert Hessler,
John S. Wright,
Carl L. Mees,
W. S. Blatchley,
H. W. Wiley,
M. B. Thomas,
D. W. Dennis,
C. H. Eigenmann,
C. A. Waldo,
Thomas Gray,
Stanley Coulter,
A. W. Butler,
W. A. Noyes,
J. C. Arthur,
O. P. Hay,
T. C. Mendenhall,
J. C. Branner,
J. P. D. John,
J. M. Coulter,
D. S. Jordan.

CURATORS

Botany........J. C. Arthur.
Ichthyology........C. H. Eigenmann.
Herpetology, Mammalogy, Ornithology........A. W. Butler.
Entomology........W. S. Blatchley.

# COMMITTEES, 1909-1910.

PROGRAM.

P. NAYLOR, E. S. JOHONNATT, J. S. WRIGHT

MEMBERSHIP.

COULTER, A. W. BUTLER, M. B. THOMAS

NOMINATIONS.

J. BIGNEY, L. J. RETTGER, W. A. COGSHALL

AUDITING.

. J. MOENKHAUS, G. W. BENTON, W. S. BLATCHLEY

STATE LIBRARY.

S. WRIGHT, W. S. BLATCHLEY, A. W. BUTLER
G. W. BENTON.

RESTRICTION OF WEEDS AND DISEASES.

HESSLER, J. N. HURTY, A. W. BUTLER
S. COULTER, D. M. MOTTIER.

DIRECTORS OF BIOLOGICAL SURVEY.

'ANLEY COULTER, C. R. DRYER, M. B. THOMAS
C. H. EIGENMANN, J. C. ARTHUR.

RELATIONS OF THE ACADEMY TO THE STATE.

W. MCBRIDE, M. B. THOMAS, G. CULBERTSON
W. S. BLATCHLEY.

DISTRIBUTION OF THE PROCEEDINGS.

S. WRIGHT, H. L. BRUNER, G. W. BENTON
R. E. LYONS, J. H. RANSOM.

PUBLICATION OF PROCEEDINGS.

[. L. BRUNER, Editor, D. BODINE, D. M. MOTTIER.

# OFFICERS OF THE INDIANA ACADEMY OF SCIENCE.

| Years. | President. | Secretary. | Asst. Secretary. | Press Secretary. | Treasurer. |
|---|---|---|---|---|---|
| 1885–1886 | David S. Jordan | Amos W. Butler | | | O. P. Jenkins. |
| 1886–1887 | John M. Coulter | Amos W. Butler | | | O. P. Jenkins. |
| 1887–1888 | J. P. D. John | Amos W. Butler | | | O. P. Jenkins. |
| 1888–1889 | John C. Branner | Amos W. Butler | | | O. P. Jenkins. |
| 1889–1890 | T. C. Mendenhall | Amos W. Butler | | | O. P. Jenkins. |
| 1890–1891 | O. P. Hay | Amos W. Butler | | | O. P. Jenkins. |
| 1891–1892 | J. L. Campbell | Amos W. Butler | | | C. A. Waldo. |
| 1892–1893 | J. C. Arthur | Amos W. Butler | Stanley Coulter<br>W. W. Norman | | C. A. Waldo. |
| 1893–1894 | W. A. Noyes | C. A. Waldo | W. W. Norman | | W. P. Shannon. |
| 1894–1895 | A. W. Butler | John S. Wright | A. J. Bigney | | W. P. Shannon. |
| 1895–1896 | Stanley Coulter | John S. Wright | A. J. Bigney | | W. P. Shannon. |
| 1896–1897 | Thomas Gray | John S. Wright | A. J. Bigney | | W. P. Shannon. |
| 1897–1898 | C. A. Waldo | John S. Wright | A. J. Bigney | Geo. W. Benton | J. T. Scovell. |
| 1898–1899 | C. H. Eigenmann | John S. Wright | E. A. Schultze | Geo. W. Benton | J. T. Scovell. |
| 1899–1900 | D. W. Dennis | John S. Wright | E. A. Schultze | Geo. W. Benton | J. T. Scovell. |
| 1900–1901 | M. B. Thomas | John S. Wright | E. A. Schultze | Geo. W. Benton | J. T. Scovell. |
| 1901–1902 | Harvey W. Wiley | John S. Wright | Donaldson Bodine | Geo. W. Benton | J. T. Scovell. |
| 1902–1903 | W. S. Blatchley | John S. Wright | Donaldson Bodine | G. A. Abbott | W. A. McBeth. |
| 1903–1904 | C. L. Mees | John S. Wright | J. H. Ransom | G. A. Abbott | W. A. McBeth. |
| 1904–1905 | John S. Wright | Lynn B. McMullen | J. H. Ransom | G. A. Abbott | W. A. Mcbeth. |
| 1905–1906 | Robert Hessler | Lynn B. McMullen | J. H. Ransom | Charles R. Clark | W. A. McBeth. |
| 1906–1907 | D. M. Mottier | Lynn B. McMullen | J. H. Ransom | G. A. Abbott | W. A. McBeth. |
| 1907–1908 | Glenn Culbertson | J. H. Ransom | A. J. Bigney | G. A. Abbott | W. A. McBeth. |
| 1908–1909 | A. L. Foley | J. H. Ransom | A. J. Bigney | G. A. Abbott | W. A. McBeth. |
| 1909–1910 | P. N. Evans | Geo. W. Benton | A. J. Bigney | John W. Woodhams. | W. J. Moenkhaus |

# CONSTITUTION.

## ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SEC. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science, to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other resources and riches of the State; to arrange and prepare for publication such reports of investigation and discussions as may further the aims and objects of the Academy as set forth in these articles.

Whereas, The State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or of one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

## ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident members or active members.

SEC. 2. Any person engaged in any department of scientific work, or in original research in any department of science, shall be eligible to active membership. Active members may be annual or life members. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars and thereafter an annual fee of one dollar. Any person who shall at one time contribute fifty dollars to the funds of this Academy may be elected a life member of

the Academy, free of assessment. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Applications for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

SEC. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

## ARTICLE III.

SECTION 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a President, Vice-President, Secretary, Assistant Secretary, Press Secretary and Treasurer, who shall perform the duties usually pertaining to their respective offices and in addition, with the ex-Presidents of the Academy, shall constitute an Executive Committee. The President shall, at each annual meeting, appoint two members to be a committee, which shall prepare the programs and have charge of the arrangements for all meetings for one year.

SEC. 2. The annual meeting of this Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the Executive Committee. There shall also be a summer meeting at such time and place as may be decided upon by the Executive Committee. Other meetings may be called at the discretion of the Executive Committee. The past Presidents, together with the officers and Executive Committee, shall constitute the council of the academy, and

represent it in the transaction of any necessary business not especially provided for in this constitution, in the interim between general meetings.

SEC. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

# BY-LAWS.

1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The President shall deliver a public address on the morning of one of the days of the meeting at the expiration of his term of office.

3. The Press Secretary shall attend to the securing of proper newspaper reports of the meetings and assist the Secretary.

4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the President and countersigned by the Secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of business.

# MEMBERS.

## *FELLOWS.*

| | | |
|---|---|---|
| †G. A. Abbott | *1908 | Fargo, N. D. |
| R. J. Aley | 1898 | Indianapolis. |
| J. C. Arthur | 1894 | Lafayette. |
| J. W. Beede | 1906 | Bloomington |
| George W. Benton | 1896 | Indianapolis. |
| A. J. Bigney | 1897 | Moores Hill. |
| Katherine Golden Bitting | 1895 | Lafayette. |
| W. S. Blatchley | 1893 | Indianapolis. |
| Donaldson Bodine | 1899 | Crawfordsville. |
| H. L. Bruner | 1899 | Indianapolis. |
| Severance Burrage | 1898 | Lafayette. |
| A. W. Butler | 1893 | Indianapolis. |
| W. A. Cogshall | 1906 | Bloomington. |
| †Mel. T. Cook | 1902 | Newark, Del. |
| †John M. Coulter | 1893 | Chicago, Ill. |
| Stanley Coulter | 1893 | Lafayette. |
| U. O. Cox | 1908 | Terre Haute. |
| Glenn Culbertson | 1899 | Hanover. |
| E. R. Cumings | 1906 | Bloomington. |
| S. C. Davisson | 1908 | Bloomington. |
| D. W. Dennis | 1895 | Richmond. |
| C. R. Dryer | 1897 | Terre Haute. |
| C. H. Eigenmann | 1893 | Bloomington. |
| Percy Norton Evans | 1901 | West Lafayette. |
| A. L. Foley | 1897 | Bloomington. |
| M. J. Golden | 1899 | Lafayette. |
| †W. F. M. Goss | 1893 | Urbana, Ill. |
| Thomas Gray (Died Dec. 19, 1908) | 1893 | Terre Haute. |
| A. S. Hathaway | 1895 | Terre Haute. |
| W. K. Hatt | 1902 | Lafayette. |
| Robert Hessler | 1899 | Logansport. |

*Date of election.
†Non-resident.

| | | |
|---|---|---|
| †H. A. Huston | *1893 | Baltimore, Md. |
| Edwin S. Johonnatt | 1904 | Terre Haute. |
| Robert E. Lyons | 1896 | Bloomington. |
| W. A. McBeth | 1904 | Terre Haute. |
| V. F. Marsters | 1893 | Santiago, Chili. |
| C. L. Mees | 1894 | Terre Haute. |
| †J. A. Miller | 1904 | Swarthmore, Pa. |
| W. J. Moenkhaus | 1901 | Bloomington. |
| D. M. Mottier | 1893 | Bloomington. |
| J. P. Naylor | 1903 | Greencastle. |
| †W. A. Noyes | 1893 | Urbana, Ill. |
| Rolla R. Ramsey | 1906 | Bloomington. |
| J. H. Ransom | 1902 | Lafayette. |
| L. J. Rettger | 1896 | Terre Haute. |
| David Rothrock | 1906 | Bloomington. |
| J. T. Scovell | 1894 | Terre Haute. |
| Albert Smith | 1908 | Lafayette. |
| †Alex Sm'th | 1893 | Chicago, Ill. |
| W. E. Stone | 1893 | Lafayette. |
| †Joseph Swain | 1898 | Swarthmore, Pa. |
| M. B. Thomas | 1893 | Crawfordsville. |
| †C. A. Waldo | 1893 | St. Louis, Mo. |
| †F. M. Webster | 1894 | Washington, D.C. |
| Jacob Westlund | 1904 | Lafayette. |
| †H. W. Wiley | 1895 | Washington, D..C. |
| W. W. Woollen | 1908 | Indianapolis. |
| John S. Wright | 1894 | Indianapolis. |

*Date of election.
†Non-resident.

## *NON-RESIDENT MEMBERS.*

| | |
|---|---|
| George H. Ashley | Washington, D. C. |
| J. C. Branner | Stanford University, Cal. |
| M. A. Brannon | Grand Forks, N. D. |
| D. H. Campbell | Stanford University, Cal. |
| H. W. Clark | Washington, D. C. |
| H. B. Dorner | Urbana, Ill. |
| A. Wilmer Duff | Worcester, Mass. |

B. W. Everman.................................Washington, D. C.
W. A. Fiske...................................Los Angeles, Cal.
C. W. Garrett.................................Pi tsburg, Pa.
Charle H. Gilbert.............................Stanford University, Cal.
C. W. Greene..................................Columbia, Mo.
C. W. Hargitt.................................Syracuse, N. Y.
O. P. Hay.....................................Washington, D. C.
Edward Hughes.................................Stockton, Cal.
O. P. Jenkins.................................Stanford University, Cal.
C. T. Knipp...................................Urbana, Ill.
D. S. Jordan..................................Stanford University, Cal.
J. S. Kingsley................................Tufts College, Mass.
D. T. MacDougal...............................Tucson, Arizona.
L. B. McMullen................................Valley City, N. D.
T. C. Mendenhall..............................Worcester, Mass.
J. F. Newsom..................................Stanford University, Cal.
A. H. Purdue..................................Fayetteville, Ark.
A. B. Reagan..................................Orr, Minn.
J. R. Slonaker................................Stanford University, Cal.
Alfred Springer...............................Cincinnati, Ohio.
Robert B. Warder (Deceased)...................Washington, D. C.
Ernest Walker.................................Fayetteville, Ark.
G. W. Wilson..................................Fayette, Ia.

## *ACTIVE MEMBERS.*

C. E. Agnew...................................Delphi.
L. E. Allison.................................West Lafayette.
H. W. Anderson................................Ladoga.
Paul Anderson.................................Crawfordsville.
H. F. Bain....................................San Francisco, Cal.
Walter D. Baker...............................Indianapolis.
Walter M. Baker...............................Red Key.
Edward Hugh Bangs.............................Indianapolis.
Howard J. Banker..............................Greencastle.
H. E. Barnard.................................Indianapolis,
W. H. Bates...................................West Lafayette.
Guido Bell....................................Indianapolis.

| | |
|---|---|
| Bennett | Valparaiso. |
| s Billings | West Lafayette. |
| Eldridge Bishop | Indianapolis. |
| Black | Bloomington. |
| n N. Blanchard | Greencast'e. |
| S. Bond | Richmond. |
| Bourke | Edinburg. |
| C. Boyer | Lebanon. |
| Brandon | Bloomington. |
| . Breeze | Lafayette. |
| Brossmann | Indianapo'is. |
| Br ce | Terre Haute. |
| L. Butler | Indianapolis. |
| d N. Canis | Indianapolis. |
| e Carman | Indianapolis. |
| Clinton Carson | Detroit, Mich. |
| n S. Chamberlain (Deceased) | Indianapolis. |
| Chansler | Bicknell. |
| W. Childs | Kokomo. |
| Christie | Cincinnati, O. |
| Clark | Connersville. |
| D. Clayton | Portland. |
| Clem | Monroeville. |
| s Clickner | Silverwood, R. D. No. 1. |
| s A. Coffey | Petersburg. |
| n Clifford Cox | Columbus. |
| ragwall | Crawfordsville. |
| Crowell | Franklin. |
| . Cunningham | Indianapolis. |
| E. Daniels | Laporte. |
| avis | West Lafayette. |
| C. Davis | Terre Haute. |
| E. Deam | Indianapolis. |
| em | Frankfort. |
| Dietz | Indianapolis. |
| Dimonds | Indianapolis. |
| oan. | Westfield. |
| n | Syracu e. |

Hans Duden.....Indianapolis.
Arthur E. Dunn.....Logansport.
Herbert A. Dunn.....Logansport.
M. L. Durbin.....Anderson.
J. B. Dutcher.....Philadelphia, Penn.
Samuel E. Earp.....Indianapolis.
A. A. Eberly.....Nowata, Okla.
C. R. Eckler.....Indianapolis.
Max Mapes Ellis.....Vincennes.
H. E. Enders.....West Lafayette.
Samuel G. Evans.....Evansville.
William P. Felver.....Logansport.
C. J. Fink.....Crawfordsville.
M. L. Fisher.....West Lafayette.
A. S. Fraley.....Linden.
Austin Funk.....Jeffersonville.
John D. Gabel.....North Madison.
Andrew W. Gamble.....Logansport.
H. O. Garman.....Indianapolis.
J. B. Garner.....Crawfordsville.
Florence A. Gates.....Wabash.
Robert G. Gillum.....Terre Haute.
E. R. Glenn.....Brookville.
Frederic W. Gottlieb.....Morristown.
Vernon Gould.....Rochester.
Frank Cook Greene.....New Albany.
Earl Grimes.....Russellv lle.
Walter L. Hahn.....Springfield, S. D.
C. F. Harding.....West Lafayette.
Mary T. Harman.....State College, Pa.
Walter W. Hart.....Indianapolis.
Victor Hendricks.....St. Louis, Mo.
L. R. Hessler.....Crawfordsville.
John P. Hetherington.....Logansport.
C. E. Hiatt.....Philadelphia, Pa.
John E. Higdon.....Indianapolis.
Frank R. Higgins.....Terre Haute.
S. Bella Hilands.....Madison.

randt..............................Logansport.
....................................Lafayette.
....................................Logansport.
....................................Richmond.
bard...............................South Bend.
....................................Indianapolis.
....................................West Lafayette.
....................................Indianapolis.
e...................................Terre Haute.
....................................Lebanon.
....................................Durham, N. H.
....................................Lafayette.
....................................Greenfield.
....................................West Lafayette.
....................................West Lafayette.
....................................Terre Haute.
....................................West Lafayette.
....................................Lafayette.
....................................West Lafayette.
....................................Indianapolis.
laskey..........................
1...................................Crawfordsville.
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ain.................................West Lafayette.
hester..............................Minneapolis, Minn.
waring..............................Bloomington.
Mason..............................Borden.
....................................Indianapolis.
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ller.................................Indianapolis.
....................................Indianapolis.
....................................West Lafayette.
....................................St. Louis, Mo.
Moore..............................Indianapolis.
rer.................................Marion.
....................................Crawfordsville.
....................................Terre Haute.
ey..................................Bedford.

Charles E. Newlin . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
J. A. Nieuwland . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Notre Dame.
G. A. Osner . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Crawfordsville.
D. A. Owen . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Franklin.
Everett W. Owen . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
Ferman L. Pickett . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bloomington.
Rollo J. Pierce . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Richmond.
Ralph B. Polk . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Greenwood.
James A. Price . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Ft. Wayne.
W. H. Rankin . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Ithaca, N. Y.
C. A. Reddick . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Crawfordsville.
C. J. Reilly . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Syracuse.
Allen J. Reynolds . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
George L. Roberts . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Lafayette.
J. Schramm . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Crawfordsville.
E. A. Schultze . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Laurel.
Will Scott . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bloomington.
Charles Wm. Shannon . . . . . . . . . . . . . . . . . . . . . . . . . Brazil.
Fred Sillery . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
Oscar W. Silvey . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . W. Lafayette.
C. Piper Smith . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Logan, Utah.
Essie Alma Smith Shannon . . . . . . . . . . . . . . . . . . . . . Bloomington.
E. R. Smith . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
Geo. Spitzer . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Lafayette.
Brenton L. Steele . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Pullman, Wash.
Chas. Stoltz . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . South Bend.
J. M. Stoddard . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Milo H. Stuart . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
Julius W. Sturmer . . . . . . . . . . . . . . . . . . . . . . . . . . . . Lafayette.
J. C. Taylor . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Logansport.
Albert W. Thompson . . . . . . . . . . . . . . . . . . . . . . . . . . Owensville.
A. D. Thorburn . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
Iro C. Trueblood (Miss) . . . . . . . . . . . . . . . . . . . . . . . Greencastle.
W. P. Turner . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . West Lafayette.
Chas. A. Vallance . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indianapolis.
J. M. Van Hook . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bloomington.
W. B. Van Gorder . . . . . . . . . . . . . . . . . . . . . . . . . . . . Lyons.
H. S. Voorhees . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Ft. Wayne.

| | |
|---|---|
| ınk B. Wade | Indianapolis. |
| ther C. Weeks | West Lafayette. |
| son L. Weems | Valparaiso. |
| niel T. Weir | Indianapolis. |
| nes E. Weyant | Indianapolis. |
| ·ges Wheeler | Montmorenci. |
| E. White | Connersville. |
| 'red T. Wiancko | Lafayette. |
| lliam L. Woodburn | Bloomington. |
| ın W. Woodhams | Indianapolis. |
| rbert Milton Woollen | Indianapolis. |
| F. Woolsey | Cleveland, O. |
| A. Young | West Lafayette. |
| ›ob P. Young | Huntington. |
| E. Young | West Lafayette. |
| J. Young | Washington, D. C. |
| cy Youse | Terre Haute. |
| A. Zehring | West Lafayette. |
| arles Zeleny | Urbana, Ill. |

| | |
|---|---|
| Fellows, resident | 46 |
| Non-resident | 12 |
| Members, active | 183 |
| Members, non-resident | 30 |
| Total | 271 |

## THOMAS GRAY.

Dr. Thomas Gray, a member of the Indiana Academy of Science since 1888, was President in 1897-8, died in Terre Haute, Ind., December 19, 1908.

He was born in Lochgelly, Scotland, February 4, 1850, received his early education in the schools of the district and, after serving an apprenticeship in handicraft, entered the University of Glasgow, graduating from the Mechanical Engineering course, with high honors, in 1874. After graduation he became Research Assistant to Lord Kelvin (Sir William Thompson). His work lay especially in the direction of absolute measurements in electricity and magnetism, electrical and heat conductivity of glasses of various compositions and the variation in conductivity of metals under stress. In 1878 he became Professor of Telegraph Engineering in the University of Tokio, Japan. While there he became interested in earthquake phenomena and invented several seismographs and investigated the elastic constants of many rocks. In 1881 he returned to Scotland, becoming Lord Kelvin's personal assistant, undertaking investigations in connection with practical problems in electricity then coming to the front. He developed and investigated methods for electrolytic measurements of electric currents and largely designed the well known Kelvin balances. He was Lord Kelvin's and Flemming Jenkins' representative as engineer for the Commercial Cable Companies and supervised the laying of the Bennett-Mackay transatlantic cables. In 1888 he came to Terre Haute, Ind., as professor of dynamic engineering in the Rose Polytechnic Institute, which position he held until his death. His investigational work was now mainly of an engineering character, too well known to recount. He was the author of several important works, the best known perhaps being the Smithsonian Physical Tables. The articles in the Encyclopedia Brittanica on telegraphs and telephones were from his pen. He also edited the definitions in electricity and magnetism for the Century Dictionary. He was the author of about sixty papers on scientific subjects, communicated to engineering societies and scientific journals. He was a member of most of the American scientific and engi-

neering societies and held high offices in a number of them. His interest in the work of the Indiana Academy of Science made him a faithful and regular attendant at most of its meetings. On the roll of American and European scientists, his name stands high, and his contribution to science, as well as his work in the educational field while in this country, has been of the highest order.

*Be it Resolved*, That the Indiana Academy of Science recognize the services of Dr. Thomas Gray as investigator, experimentalist, teacher, and loyal supporter of the Academy by placing these resolutions and a sketch of his life upon the minutes of this meeting and print them in the volume of Proceedings.

The Committee: C. L. MEES.
A. W. BUTLER.
G. W. BENTON.

Adopted by the Indiana Academy of Science, in session in Indianapolis, Nov. 27, 1909.

## W. H. RAGAN.

W. H. Ragan, for many years connected with the United States Department of Agriculture, and who recently died, was one of the charter members of the Indiana Academy of Science. He was one of that company, of which a number of members are here today, who were present at the first meeting. At that time he was a member of the faculty of DePauw University. He has had a deep interest in the progress of science, and especially in its application to horticulture, to which line of usefulness his life was devoted.

We make a tribute herewith to his memory.

The Committee: C. L. MEES.
A. W. BUTLER.
G. W. BENTON.

Adopted by the Indiana Academy of Science, in session in Indianapolis, Nov. 27, 1909.

TWENTY-FIFTH ANNUAL MEETING

# [DIANA ACADEMY OF SCIENCE

CLAYPOOL HOTEL, INDIANAPOLIS, IND.

NOVEMBER 25, 26 AND 27, 1909

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*Officers and Ex-Officio Executive Committee*

FOLEY, President
EVANS, Vice-President
RANSOM, Secretary
A. J. BIGNEY, Assistant Secretary
G. A. ABBOTT, Press Secretary
W. A. MCBETH, Treasurer

GLENN CULBERTSON
DAVID MOTTIER
ROBERT HESSLER
JOHN S. WRIGHT
C. L. MEES
W. S. BLATCHLEY
H. W. WILEY
D. W. DENNIS
C. H. EIGENMANN
C. A. WALDO
THOMAS GRAY
STANLEY COULTER
AMOS W. BUTLER
W. A. NOYES
M. B. THOMAS
J. C. ARTHUR
O. P. HAY
T. C. MENDENHALL
JOHN C. BRANNER
J. P. D. JOHN
JOHN M. COULTER
DAVID STARR JORDAN

he meetings of the Indiana Academy of Science Thursday evening, iber 25th; Friday, November 26th, morning and afternoon; Satur- November 27th, morning; and the informal dinner Thursday night, ncheon Friday noon and the banquet Friday night, will be at the ol Hotel.

he rates quoted by the management are $2.00 per day and upward European plan and $4.00 per day and upward on the American plan. two or more persons occupy a room, the rates are $1.50 and upward y, European plan, and $3.50 and upward per day, American plan. reservation and reservations for the banquet should be made at once. stereopticon will be provided.

*Committee on 25th Meeting*

AMOS W. BUTLER, Chairman

B. THOMAS
E. STONE
C. L. MEES
W. J. MOENKHAUS
H. L. BRUNER
J. P. NAYLOR

*Local Committee*

GEORGE W. BENTON  JOHN S. WRIGHT  JOHN W. WOODHAMS

## OUTLINE OF GENERAL PROGRAM

*Thursday, November 25*

| | |
|---|---|
| 4:00 p. m. | Meeting of the Executive Committee |
| 6:30 p. m. | Informal dinner |
| 8:00 p. m. | Opening session |
| | Business |
| | Address—"By Packtrain to the Tiptop of the United States in Quest of the Golden Trout," B. W. Evermann, U. S. Bureau of Fisheries, Washington D. C. |

*Friday November 26*

| | |
|---|---|
| 9:00 a. m. | Business |
| | President's Address—"Recent Progress in Physics," Dr. A. L. Foley, Bloomington |
| | Address—"Recent Progress in Chemistry," Dr. H. W. Wiley, Chief of the Bureau of Chemistry, U. S. Department of Agriculture, Washington, D. C. |
| | Address—"Recent Progress in Botany," Dr. John M. Coulter, Department of Botany, Chicago University |
| | Greetings from other societies |
| 12:00 noon | Informal luncheon |
| 2:00 p. m. | Address—"Darwin Fifty Years After," Dr. David Starr Jordan, President Leland Stanfard Jr. University, President American Association for the Advancement of Science |
| 3:00 p. m. | Section meetings |
| | The Academy will meet in sections. A few papers, preferably those of historical character, will be read |
| 8:00 p. m. | Banquet—D. W. Dennis, Toastmaster |

*Saturday, November 27*

| | |
|---|---|
| 9:00 a. m. | Business |
| | Address—"Methods and Materials Used in Soil Testing," H. A. Huston, Chicago |
| | Address—"Federal Control of International and Interstate Waters," B. W. Evermann, U. S. Bureau of Fisheries |
| | Address—"The Speed of Migration of Salmon in the Columbia River," Charles W. Greene, University of Missouri |
| | Address—"Some Hoosier and Academy Experiences," C. A. Waldo, Washington University, St. Louis, Mo. |

Suggestions: Plans for the Academy—

| | |
|---|---|
| John S. Wright | W. E. Stone |
| Stanley Coulter | C. Leo Mees |
| H. E. Barnard | W. A. Cogshall |

## PAPERS TO BE READ

Unless otherwise stated, papers will be understood to be limited to fifteen minutes. The first circular of the Committee stated: "These papers will be presented, and while probably few of them will be read at the meeting, they will be printed in the Proceedings."

### *General*

Thought Stimulation, Under What Conditions Does It Occur? 10 minutes ........................................... Robert Hessler
Does Blood Tell? ................. William B. Streeter Greensboro, N. C.
Hygiene of Indoor Swimming Pools, with Suggestions for Practical Disinfection. 25 minutes ........................ Severance Burrage
Indiana Problems in Sewage Disposal. 10 minutes.......... R. L. Sackett
Defective Elementary Science ........................ William N. Heiney
Some Hoosier and Academy Experiences
C. A. Waldo, Washington University
Darwin Fifty Years After
David Starr Jordan, President Leland Stanford Jr. University
The Zia Mesa and Ruins .............................. Albert B. Reagan
That Erroneous Hiawatha ............................ Albert B. Reagan
The Medicinal Value of Eupatorium Perfoliatum ............ A. J. Bigney

### *Chemistry*

Methods and Materials Used in Soil Testing. 25 minutes
H. A. Huston, Chicago, Ill.
The Discovery of the Composition of Water (illustrated)
W. A. Noyes, University of Illinois
Molecular Rearrangements of Derivatives of Camphor........ W. A. Noyes
Use of Refractometer in Dry Substance Estimation
A. Hugh Bryan, U. S. Bureau of Chemistry
Conductivity and Ionization of Solutions of Certain Salts in Ethyl Amine. 10 minutes .................................. E. G. Mahin
Recent Progress in Chemistry.
H. W. Wiley, Chief of the Bureau of Chemistry, U. S. Department of Agriculture
Electric Osmose. 15 minutes .......................... Harry N. Holmes
A Study of the Chemical Composition of Butter Fat
O. F. Hunziker and George Spitzer

On a New Complex Cyanogen Compound.................A. R. Middleton
The Determination of Endothermic Gases by Combustion...A. R. Middleton

*Mathematics*

Methods in Solid Analytics. 15 minutes..............Arthur S. Hathaway
Motion of n Bodies. 20 minutes......................Arthur S. Hathaway
Discussion of the Regular Inscribed Pentagon. 5 minutes...John C. Gregg
If the Bisectors of Two Angles of a Triangle are Equal, Those Angles are Equal. 5 minutes ...............................John C. Gregg

*Physics*

Direct Reading Accelerometers. 20 minutes .................C. R. Moore
Recent Work in Wood Physics. 10 minutes .................W. K. Hatt
Expansion of Paving Blocks. 10 minutes ....................W. K. Hatt
Notes on the Strength of Concrete Building Blocks. 10 minutes H. H. Schofield
Slip of Riveted Joints. 10 minutes ......................Albert Smith
Polarization of Cadmium Cells .........................Rolla R. Ramsey
Investigation of a Point Discharge in a Magnetic Field....Oscar W. Silvey
The Tenacity of Gelatine ..............................Arthur L. Foley
Objections to LaPlace's Theory of Capillarity............Arthur L. Foley
Cohesion of Water as Modified by Certain Dissolved Salts. 10 minutes ..........................................Edwin Morrison

*Geology and Geography.*

Some Features of Delta Formation. 15 minutes........Charles R. Dryer
A Physiographic Survey of an Area Near Terre Haute, Ind. 25 minutes ............................Charles R. Dryer, Melvin K. Davis
The Collecting Area of the Waters of the Hot Springs of Hot Springs, Ark. 15 minutes ..............A. H. Purdue, University of Arkansas
The Geographical and Geological Distribution of Some Pleistocene Mammals ........................O. P. Hay, U. S. National Museum
On the Restoration of Skeletons of Fossil Vertebrates..........O. P. Hay
Where Do the Lance Creek ("Ceratops") Beds Belong, in the Cretaceous or Tertiary?....................................Oliver P. Hay
Paleontology and the Recapitulation Theory. 50 minutes....E. R. Cumings
The Tippecanoe, an Infantile Drainage System. 10 minutes..W. A. McBeth
Observations on Cyclones and Anti-Cyclones of North Temperate Latitudes. 10 minutes ..................................W. A. McBeth

*Zoology.*

A Paired Entoplastron in Trionyx and Its Significance. 15 minutes .....................Henry H. Lane, Oklahoma State University

Physiological Explanation of the Psycho-Physical Law of Weber. 15 minutes ............................................Guido Bell
On the Nature and Source of Thrombin. 12 minutes..........L. J. Rettger
Federal Control of International and Interstate Waters
B. W. Evermann, U. S. Bureau of Fisheries
By Packtrain to the Tiptop of the United States in Quest of the Golden Trout (illustrated) ..............................B. W. Evermann
The History of Zoology in Indiana. 15 minutes.........C. H. Eigenmann
An Analytic Study of the Faunal Changes in Indiana. 25 minutes
Walter L. Hahn, South Dakota State Normal School
Some Notes on Parasites Found in Frogs in the Vicinity of St. Paul, Minn. 20 minutes.................H. L. Osborn, Hamlin University
The Mocking Bird About Moores Hill, Indiana..............A. J. Bigney
Cross-Fertilization Among Fishes.......................W. J. Moenkhaus
Observations on Woodpeckers. 5 minutes...............John T. Campbell
Paroxysmal Hæmoglobinuria. 10 minutes................Oliver P. Terry
The Evolution of Insect Galls as Illustrated by the Genus Amphibolips ..............................Mel T. Cook, Delaware College
The Speed of Migration of Salmon in the Columbia River
Charles W. Greene, University of Missouri
Observations on Cerebral Localization
J. Rollin Slonaker, Leland Stanford Jr. University
The Nasal Muscles of Vertebrates..........................H. L. Bruner

*Botany.*

Physiological Apparatus .............................Frank M. Andrews
Some Monstrosities in Plants.........................Frank M. Andrews
A List of Algæ ....................................Frank M. Andrews
Re-Vegetation of the Salton Basin (illustrated)
D. T. MacDougal, Director Desert Laboratory, Tucson, Ariz.
Forest Conditions in Indiana. 15 minutes................Stanley Coulter
Additions to Indiana Flora, Number 4. 3 minutes......Charles C. Deam
The Development of the Reproductive Organs of Chara fragilis. 20 minutes .........................................George N. Hoffer
Right and Wrong Conceptions of Plant Rusts................J. C. Arthur
The Effect of Preservatives on the Development of Penicillium. 10 minutes ................................Katherine Golden Bitting
Recent Progress in Botany...........John M. Coulter, Chicago University
Further Notes on Timothy Rust..........................Frank D. Kern

*Editorial Notice.*

All members of the Academy will doubtless be ready to assist in any efforts put forth having in view correct and early publication of the Pro-

ceedings. To this end the following conditions of publication are announced by the editor:

1. All papers to be included in the report of 1909 must be in the hands of the editor not later than December 15, 1909.

2. All papers should be typewritten as far as the nature of the subject will allow.

3. All tracings and maps should be drawn to correspond with the size of the page of the Proceedings, and must come within the following limits: 4½x7. If necessary, it may be made to cover two pages, or measure 8½x11.

4. Authors are especially requested to carefully mark and number all illustrations and to carefuly indicate in the MSS. the exact location of such illustrations.

5. To secure proper representation of mathematical work, authors are particularly cautioned to send in carefully traced figures on separate paper.

6. The limits of the appropriation require that all illustrations shall be in one color, and either photographs or etchings. As a consequence, all illustrations must be in black and white.

## Resolution Providing for the Celebration of the Twenty-fifth Anniversary of the Indiana Academy of Science.

*Resolved*, That in view of the fact that the next meeting will be the Twenty-fifth Annual Meeting of this Academy, a special effort be made at that time to celebrate the quarter centennial of its organization.

That a committee of seven be appointed to have charge of the program and all necessary arrangements for such meeting.

That the time and place of the next meeting be left to said committee.

That an effort be made to have present all the living ex-presidents and all of the living charter members of the Academy. Also that all the universities, colleges and other educational institutions of the State, all scientific organizations, including the State Medical Society, Indiana Engineering Society, Indiana Section of the American Chemical Society, State Science Teachers' Association, and all individuals interested in scientific work and the press of the State be cordially invited to co-operate to make this a successful meeting and memorable occasion.

Adopted November 28, 1908.

# The Beginning of the Indiana Academy of Science.

By Amos W. Butler.

In my early years the lack of association with persons who were interested in scientific pusuits and of opportunity to refer to books on scientific subjects was greatly felt. I planned to interest several persons in establishing a local society which would bring kindred spirits together. This resulted in the organization of the Brookville Society of Natural History in 1881. That year, for the first time, I attended the meeting of the American Association for the Advancement of Science at Cincinnati. There I had the pleasure of meeting many persons of whom I had only known by reading. This was the beginning of many acquaintances that have been permanent, helpful and inspiring. In my efforts to study local natural history I found it difficult to obtain information from students in other parts of the State. In talking with others I found they had had the same difficulty. In the winter of 1883-1884, the need of a State organization was strongly impressed upon me. Correspondence was begun with a number of persons whose names were prominent in scientific work of the State, and the majority of them favored such an organization. Among these were Dr. David Starr Jordan, Dr. J. P. D. John, Professors John M. Coulter, Stanley Coulter, Philip S. Baker, Daniel Kirkwood, Richard Owen and Oliver P. Jenkins. There were others who discouraged it. The subject was fresh in mind at the time of the meeting of the American Association for the Advancement of Science at Ann Arbor in 1884. There opportunity was given to talk the subject over, and for the first time I met Dr. John C. Branner, who had just been appointed professor of geology at Indiana University, and he strongly urged the formation of such a society. Finally it was decided to call a meeting to organize an Indiana Society. The Brookville Society of Natural History, as the most active organization of its kind in the State, was asked to take the initiative and call the first meeting. Accordingly that society appointed a committee for that purpose, consisting of Rev. David R. Moore, its president, Dr. S. P. Stoddard and Amos W. Butler. The meeting was called for Indianapolis on December 29, 1885. The plan was to have a series of papers on the status of different branches of science in Indiana. The meeting was held in the Marion County court house. The program included the following papers:

"Meteorology" ........................................ Wm. H. Ragan
"Progress in the Study of Mammalogy in Indiana" ........ Edgar R. Quick
"Sketch of the Work Accomplished for Natural and Physicial Science in Indiana" ........................................ Richard Owen
"Sketch of C. S. Rafinesque" ............................ D. S. Jordan
"Work Done in Icthyology in Indiana" ..................... D. S. Jordan
"Work Done in Botany in Indiana" ..................... John M. Coulter
"Work Done in Physics in Indiana" ........................ J. P. Naylor
"Work Done in Study of the Lower Invertebrates" ........ O. P. Jenkins
"Present Condition of the Study of Indiana Herpetology" ...... O. P. Hay
"The Study of Entomology in Indiana" ...................... P. S. Baker
"The Present Knowledge of Indiana Mineralogy" ....... Maurice Thompson
"Work Done for Geology in Indiana" .................. Ryland T. Brown
"Chemistry" ........................................ R. B. Warder
"The Present Condition of Indiana Conchology" .......... David R. Moore
"Indiana Statistics" ...................................... J. B. Conner
"The Past and Present of Indiana Ornithology" .......... Amos W. Butler
"Geography" ........................................ J. T. Scovell
"Astronomy" ........................................ David Kirkwood

(Of these only Richard Owen and David Kirkwood were absent, and their papers were read by others.)

Dr. J. P. D. John was chosen president pro tem. There were about forty persons present, representing most of the educational institutions of the State, and including most of the scientific workers. Dr. David Starr Jordan was chosen first president and Amos W. Butler the first secretary. A constitution and by-laws were adopted. Since that time regular annual meetings have been held. All but one, which was held at Lafayette, have been held in Indianapolis, and until recently spring meetings at different points in the State. The first one of these was appropriately held at Brookville May 20-22, 1886.

The following persons are mentioned in minutes of December 29, 1885, as being present and taking part in the meeting:

J. P. D. John, Greencastle.
A. W. Butler, Brookville.
O. P. Jenkins, Greencastle.
J. C. Branner, Bloomington.
S. P. Stoddard, M.D., Brookville.
*W. H. Ragan, Greencastle.
E. R. Quick, Brookville.
D. R. Moore, Brookville.
D. S. Jordan, Bloomington.
J. M. Coulter, Crawfordsville.
J. P. Naylor, Bloomington.
O. P. Hay, Irvington.
*P. S. Baker, Greencastle.
*Maurice Thompson, Crawfordsville.
J. B. Conner, Indianapolis.
*T. B. Redding, New Castle.
*Ryland T. Brown, Indianapolis.
*R. B. Warder, Lafayette.
J. T. Scovell, Terre Haute.

*Deceased.

The following persons' names appear on the treasurer's book for that meeting, and they were probably present:

D. W. Dennis, Richmond.
*Joseph Moore, Richmond.
Stanley Coulter, Terre Haute.
B. W. Evermann, Bloomington.
S. E. Meek, Bloomington.
C. H. Eigenmann, Bloomington.
*J. L. Campbell, Crawfordsville.
D. A. Owen, Franklin.
C. R. Dryer, Fort Wayne.
A. J. Phinney, M. D., Muncie.
C. A. Waldo, Terre Haute.
C. W. Hargitt, Moores Hill.
*W. P. Shannon, Greensburg.
*T. J. McAvoy, Indianapolis.
L. D. Waterman, M. D., Indianapolis.
John Hurty, M. D., Indianapolis.
F. M. Webster, Lafayette.
*F. Stein, Indianapolis.

*Deceased.

Of about forty persons in attendance upon the first meeting, twelve are present at this meeting.

# GREETINGS FROM INDIANA ASSOCIATIONS.

## FROM THE INDIANA STATE TEACHERS' ASSOCIATION.

BY GEO. W. BENTON.

Mr. President and Members of the Academy: In the absence of Dr. Robert J. Aley, State Superintendent, and president-elect of the Indiana State Teachers' Association, it has devolved upon me and is my great privilege as retiring president to extend to you the greetings of the teachers of the State, and to congratulate you upon the completion of the series of notable meetings culminating in this anniversary.

It is peculiarly fitting that we do this in view of the importance of each of these societies, and of the part which each has had, and is destined to continue to perform in the life history of the State of Indiana.

The State Teachers' Association last December passed its fifty-fifth milestone, and in its uninterrupted history of fifty-four years has marked the successive stages of educational progress in the State, and has had an increasing influence in establishing standards and in directing the current of educational thought. Many of its officers and members have become prominent in the educational work of the State and nation, and many of them have enjoyed the privilege and honor of membership and active participation in the affairs of the Academy.

No less prominent in its own sphere, through the years of its activity, we recognize the importance of the great work which the Academy has done for the State and for the nation, in the spreading of scientific knowledge, in the encouragement of research, and in the inspiration of the younger generation of science teachers to greater effort and increased efficiency. We see in the Academy the most powerful agency in the solution of the great problem of fitting the highest development of scientific thought into the general scheme of education for all the people; and we confidently look forward to the achievements of the coming years of the Academy, believing that its services to the State and to education will con-

tinue to receive that recognition which it has so richly deserved in the past, and which we now so inadequately express.

The teachers of Indiana would consider me lacking in truth and courtesy, I am sure, should I fail to give expression to the deep pleasure and pride which we feel in the great history of the Academy, and in the exceptional capacity for usefulness with which it is so richly and generously endowed.

We greet you, and we bid you Godspeed!

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## FROM THE INDIANA MEDICAL ASSOCIATION.

By Dr. S. E. Earp.

Mr. Chairman: It surely is a pleasure as well as an honor to be chosen to appear before you for the Indiana Medical Association. I am the custodian of the good-will and hearty congratulations of the Indiana State Medical Association, but it is not the casket that assumes any importance; it is the jewel I bring you. Now, when we extend our greetings we desire that they shall have a cultured application and not a provincial one. Perhaps an explanation is in order.

One of your splendid members, Prof. Stanley Coulter, recently delivered an address before The Young Physicians' Club, of which I am a member—and I am a member by virtue of the fact that all physicians are young, but some are younger than others—and Prof. Coulter in his address said that culture is an instinctive appreciation of the very best, and that provincialism is *narrowness*, the antithesis of culture. And that whenever he had come in contact with a provincialist he had two impulses, first to laugh at him, and second to kill him. He had done the first, but so far he had been able to control himself and not do the second.

So we appreciate that everything concerning you is the very best, and that it is the very best who can appreciate the best in you.

The Indiana State Medical Association has passed its golden anniversary by ten years. It has 2,690 members in good standing, and yet there are not more than twenty-five who are members of this splendid body of yours. There ought to be more. There are men who are authorities in

ɘir line who should through this channel help themselves, help the asso-
ıtion, help you and help the public by contributing what they possess.
e must learn that, taking all the departments of science, "in union there
strength."

Another important factor is this: For a time in scientific medicine, account of the number of medical institutions in this State, the interests were varied; but during the past year, for the first time in forty ars, there has not only been an amalgamation of scientific medical inrests, but there is complete unity. And now with the medical college we ve here that is under the control of one of your best Universities, India University, with its opportunities and facilities, we take it you will on hear us rapping at your door, and we trust that the latch-string will out.

We fully appreciate, as we congratulate you and bring our greetings, l that you have done and are doing for scientific medicine, and that it valuable beyond price. Again I say, as I bring you our greetings, that congratulate you most heartily.

## FROM THE INDIANA HISTORICAL SOCIETY.

By J. P. Dunn.

I have been delegated by the Indiana Historical Society to extend its eetings to the Academy of Science. This is therefore an historic greetg; just what a scientific greeting should be, I am not quite certain. In e good old days that Dr. Coulter told about, I should think the proper ing was, "Have something with me," but in the course of the great ogress that has been made in the last twenty years in the Pure Food epartment, I do not know whether that would be safe. I judge that ientific people believe all the awful revelations that have been made, ıd that they are all on the water-wagon now.

There is one thing in which I think this society and the other learned cieties of the State should be at a unit. We have a centennial in 1916. here has been some talk of having an exposition, but everybody knows hat the recent expositions have been failures, and it would be a failure

in Indiana. But it has been suggested that instead of this we erect a permanent memorial building devoted primarily to the preservation of the history of Indiana. This is being done now through the State librarian and the State museum, but we have not room enough. Mr. Blatchley has not room enough to do his work, and I understand valuable gifts have had to be refused on account of lack of room in that museum. There is also scientific work being handled in the State House by Dr. Hurty and Dr. Barnard, and we really need a building of this sort. These things ought to have ample quarters. I would like to see that centennial of 1916 celebrated by an ample building in which a museum and library could be housed, in which there would be room for laboratories and other work of the State, room for the Academy of Science, room for the Historical Society and all these other bodies.

I trust you will take that matter into consideration as you go out from here. Keep it in mind, and when you talk to your Representatives and Senators and people who have influence in the Legislature, lay it before them, and thus help in a work which I believe is of very great importance to the State of Indiana, both scientifically and historically. (Applause.)

## FROM THE INDIANA BRANCH OF THE AMERICAN CHEMICAL SOCIETY.

By Prof. R. B. Moore.

Mr. President: As representative of the Indiana branch of the American Chemical Society I extend congratulations to the Academy upon its twenty-fifth anniversary. It is needless to argue the use of such a society in the State. It does a work which none of the national societies can do, and it is needless also to state that this work has been done well. Congratulations are especially in order, to those men who founded the Academy and have borne the burden of the work since that time.

I am also glad to see that the social life of the society is receiving sufficient attention at this meeting. We have little opportunity to get together during the year; it is all the more important therefore that the social side of our meeting should be emphasized.

The Indiana branch of the American Chemical Society extends to you congratulations and greetings. (Applause.)

## FROM THE STATE PHYSICS TEACHERS' ASSOCIATION.

By Prof. J. P. Naylor.

Mr. President and Members of the Academy: I stand in the rather unfortunate position of belonging to the Committee of Arrangements for this meeting, and also representing one of the other societies. But I assure you that I did not make the assignment. The fact is I was simply held responsible for the presentation of the greetings of the State Physics Teachers' Association and tried to get a good man who could present the greeting in better words than I, although not in better spirit, I am sure.

As I look around over the faces of those present I see many members of the Physics Teachers' Association who are also members of the Academy, and it may occur to someone to ask why the Physics Teachers' Association should exist at all. The work in any science is many sided, and there are some things that can be done in the Indiana Academy and some things that can not be done. We, the physics teachers of the State, need to get together and compare notes. We want to know what the other man is doing and how he does it. This sort of work can not well be done by the Academy, for its province is rather along the line of investigation, and besides its program is always crowded; therefore the State Physics Teachers' Association.

Our association is, however, a sort of offspring of the Academy, and we look to it as the mother society. And as good children we come back at this time with our congratulations and hearty greetings, and hope for the Academy that the next two and a half decades may be even better than the past has been. We do not come like the Orientals, wishing that her shadow may never grow less but that her bright light may be ever enlarged, and that she may go on to larger accomplishments in the future. I bring you greetings. (Applause.)

## FROM INDIANA SOCIETY OF ENGINEERS.

By Chas. Brossmann.

Mr. President and Gentlemen: I feel that is is an honor to address your meeting, and am glad to speak a few words of greeting on behalf of the Indiana Engineering Society.

On your program I notice the names of more than one engineer and subjects relating to engineering work. I feel that the scientist and engineer need no introduction, for they have ever worked either together or in sequence for the betterment of man and civilization.

On the vital questions relating to the physical development of our vast industrial system the scientist has made the work of the engineer possible.

The first step belongs to your work. You took the initiative and advanced radical though perhaps unappreciated theories, labored for years to prove them, and had to work and keep the courage of your convictions to establish your point beyond question.

Your reward has not usually come from a grateful public, but you have the reward of a greater knowledge.

I wish to mention one or two papers on your program, one "A List of Algæ." A list of algæ means nothing to a community, but when an entire water system becomes clogged with Crenothrix, they cry for the scientist to find the remedy.

The subject, "The Problem of Sewage Disposal," does not appeal to a city until the stench is apparent, then succor from scientist and engineer is needed.

Most of the papers to be read, touch upon the betterment of the human race, the conservation of its health, and the country's resources.

Today Dr. Von Lendenfeld investigates the organs of flight of the best flyers of the insect orders, Lepidoptera, Hymenoptera and Diptera. The public hears and smiles.

Tomorrow the Wrights fly for hours in the upper air. The public sees and gasps in wonder and amazement.

And so the scientist needs be the silent man. Carlyle says: "The noble silent men—scattered here and there—each in his department—

silently thinking—silently working, whom no morning newspaper makes mention of—they are the salt of the earth. A country that has none, or few of them, is in a bad way."

I am glad we have many in this country, and that this State is so well represented in the "silent men"—although perhaps they will not be so silent in the ensuing two days.

Gentlemen, I am pleased and honored in extending to you the greeting and good wishes of a brother society which appreciates its debt to science. The Indiana Society of Engineers greets you and wishes you a successful meeting.

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## FROM THE INDIANA ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS.

By W. W. Hart.

Mr. Chairman: As I have sat here listening to the expressions of greeting on this occasion, I had the great pleasure of hearing the other gentlemen say the things I expected to say.

I feel that it is especially proper that our society should join with the other organizations today in expressing their interest in your Academy. In some respects, while not a child of the Academy, as is the Physics Teachers' Association, yet we might call ourselves a younger brother. Our interests are somewhat similar. We are interested in the sciences and mathematics, and I think that on that account we can appreciate better than others, possibly, the feeling of need which led to the organization of the Indiana Academy of Science twenty-five years ago. We are all of us working in a field in which we must look for sympathy, for encouragement, for inspiration, not to the public at large, because they frequently misunderstand us, but to our colleagues and fellow-workers. That, as I understand it, was one of the reasons for the organization of this society.

Also many of our number are directly indebted to some of you for the instruction and inspiration that led them to take up their life work. And we are all indebted to you for the standing you have given to scientific pursuits in the country at large.

So I bring to you today the most hearty congratulations upon your past history, and upon the glorious achievements of some of your number, and say that we wish you abundant success for the future. (Applause.)

## FROM THE INDIANA AUDUBON SOCIETY.

By William Watson Woollen.

Mr. President, Ladies and Gentlemen: The first Audubon Society was organized in New York in 1886. Its purpose was "the protection of American birds, not used for food, from destruction for mercantile purposes." In 1889 it seemed to have accomplished the purpose for which it was organized and the movement died out.

A subsequent revival of the demand for birds for millinery purposes led to a re-awakening of sentiment on the subject, and in January, 1896, a State Audubon Society was organized in Massachusetts and in October of the same year one was organized in Pennsylvania. Such societies now exist in all of the states, except perhaps a half dozen, the object of their organization being the preservation of our birds which were fast being exterminated. It was thought that the people must be educated as to the worth of our birds, and these societies entered upon that work.

In April, 1898, principally through the instrumentality of the Indiana Academy of Science, the Indiana Audubon Society was organized. I have in my office the minutes of that meeting, at which I was present. In looking over the minutes of that meeting I find the society was mainly constituted of members of this Association.

The work which has been accomplished by the Audubon Societies of the country has been immense. I am not sure that I know of any other organization which, with as little money, has accomplished so much good. Its work for good has been of such a character as to attract the attention of the people of the country and especially the Department of Agriculture at Washington. The annual reports of that department have taken account of these societies and commended them for the work which they have accomplished. You all must be aware of the legislation that

has been brought about through the influence of these societies, and especially the Lacey act passed by Congress for the protection and preservation of our birds.

I am glad to say that there is not a State in the Union which does not have its laws for the protection of our birds. In this State we have not lagged. We have placed upon our statute books the ideal law for that purpose, originally suggested by the American Ornithological Association.

Now, ladies and gentlemen, allow me to suggest in conclusion, that the membership roll of our Audubon Society contains but few names of the members of this association. We have a membership of about one hundred and fifty. Our first annual meetings under the provision of the constitution were held at Indianapolis. We learned, to our regret, however, that in this great and beautiful city there were very few people who were interested in this work. We changed our constitution. Since then we have gone to Franklin, Richmond, Shelbyville, Fort Wayne, and New Castle, where we have been received most cordially, and we hope we have done good.

Now, we bring our greetings to you, with the hope for future success, and that you will renew your love for this, one of your offspring. I have looked over the program arranged for this the twenty-fifth annual meeting of the Academy with its sixty-nine numbers and the additional numbers which Mr. Butler has read, and I find there are but two numbers which have any reference to our birds. These are No. 45, "The Mocking Bird in Indiana," and No. 47, "Observations in Woodpeckers." Now, ladies and gentlemen, to my way of thinking, this is not as it should be. I believe these other things which you have been writing and talking about are important, but of all of them the one particular thing which is of the greatest interest and value is the preservation of our birds. Without them you will have no occasion to talk about botany or any of the other things about which you have been writing and talking. It is the birds of our country to which we must look for its salvation. I thank you for the opportunity to say a word for them.

# PLANS FOR THE INDIANA ACADEMY OF SCIENCE.

JOHN S. WRIGHT: Mr. Chairman, the committee made arrangements for several persons to speak of the plans for the Academy, with reference to future expansion and development. Now, most of the points that I had in mind have been covered very adequately by the speeches which have been made at different times during the meetings, particularly last night by Dr. John M. Coulter with reference to the social side of the Academy, making the members better acquainted with each other. I feel sure that the program committee will endeavor in planning the next meeting to emphasize the social aspect more and more. Possibly a smoker will serve very well to this end. I do not suppose we would attempt a banquet of as large proportions as the one we had last night, as that would entail too much effort.

I believe the Academy will do well to enlist the interest of men who are in industrial lines. There are within this State at the present time a great many men who are in industrial lines. Mr. Brossmann, who represents the Engineering Society, referred particularly yesterday morning to the interest that engineers and chemists have in scientific work, and that their work rests upon developments along the lines of science. These men in industrial lines may properly be enlisted in the Academy interests, and I am certain we can thus enlarge the number of those engaging in the work of the Academy.

I believe that is all I care to say, because other features of the Academy work will be mentioned by those who follow.

DR. STANLEY COULTER: Mr. Chairman, I think we are a unit upon the matter of the development of the social side of the Academy. It has occurred to me that one way in which that might be brought about would be to have the Executive Committee constitute itself a committee of introduction at each session, and make it a regular part of the program to introduce the new members to the older ones. I have frequently told young men that the only way for them to broaden out was by coming in contact with these older members, and they have come to the Academy meetings, stayed a day or two and have gone home without meeting a

single one of them. We should certainly have some committee that would see that the young members are properly introduced to those with longer years of service in the State.

Another matter which should be taken up by the Academy and the Executive Committee is the length of time taken to print our reports. A man who is doing a bit of scientific work which is worth publishing, the preparation of which involves much time and labor, must wait eleven months for its appearance if he presents it to the Academy. A paper that may be of value at the time of its presentation, may not be worth nearly so much after a year has elapsed. You can not be sure that the thing you say today is the thing you would say in the same form a year from now. I think the Executive Committee should take this matter up in some definite way, and see that the proceedings are ready for distribution in less than a year from the date of meeting.

Another thing, it seems to me, that we need is that our programs should not be made up as they are now, in a comparatively haphazard fashion. In the past we had some programs that were really capital, and those who had these programs in charge would begin, say, in March or April to send the various members letters, suggesting that it would be a good time to arrange in their minds the subject they would present to the Academy, and thus, long before the Academy meeting the Executive Committee had in hand a well organized program.

In conclusion, I suggest: a recognition of the social side, an improvement in the methods of getting out our reports, so that they may be received very much more promptly than heretofore, and a return to the old method of having the Executive Committee, made up of the President, Secretary and Program Committee, feel that a large part of their work must be done before summer vacation if the meeting is to be a success. The request for my subject, under the present practice, always comes at a time when I am busier than at any other time of the year. As a consequence I send in some title that sounds well, and does not take much preparation, and trust in the main to the inspiration of the moment.

I am thoroughly in accord with Mr. Wright's suggestion that this organization is losing a very great element of strength in not having associated with it more closely the industrial scientists of the State. (Applause.)

Dr. H. E. Barnard (Indianapolis): Mr. President and Members, I cannot but feel that it is presumption for me, whose name was enrolled in the Academy but yesterday, to attempt to give advice to you who were at Brookville, and who have guided the Academy from its infancy through youth to manhood. But if there is a word I can say this morning it is to the older members, whom I would urge to give of their wisdom and advice to these young men, not only in lectures, but in heart-to-heart talks and fraternity with them. I wish to express my thanks to Dr. Coulter for his admirable toast last evening. More fraternity and fewer scientific papers I believe will be the key-note of the future of the society. Some of the papers stand a poor chance of being appreciated, because they are not understood; but we all want to know the men who write the papers, not for the papers, but for themselves. One may gain quite as much inspiration in the company of the worker in other fields as in association with his fellows, not in their papers, but in the social hour.

So I would urge more and more this fraternity among the members, especially at the spring meetings. That first gathering at the swimming pool has taken hold of me; it gives us a glimpse of an esprit de corps that will carry the Academy far, and make an Academy that we will be as proud of twenty-five years hence as we are today. (Applause.)

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President W. E. Stone: Mr. Chairman and Members of the Academy, perhaps what I have to suggest will not permit of practical application, and yet as I have been in attendance upon this meeeting I am impressed with this thought about the Academy. It has become in a sense a child of the State; it owes something to the State as an organization. It represents a body of men who certainly have a great deal of influence in shaping the future of the State. Now, it occurs to me that the particular thing which this Academy can do is in the direction of shaping public appreciation of scientific methods and scientific spirit. You can not formulate that policy for immediate action, but I submit to you if it would not be a very valuable thing if the public at large, the press, business men and public officials, had a better conception of what scientific methods and the scientific spirit stand for. How much we should be spared in the press of the sensational talk of scientific attainment; how much we should economize in the administration of the affairs of city and state; how much more it would mean to the private affairs of our citizens if there

as a conception of the idea that knowledge is to be gained on all of ıe common affairs of life which put into practice would result in effi- ency and in economy.

Now, that is a matter of slow growth—public education. We are riving to bring people to a conception of that idea in all of our schools ıd colleges, and here is a public body which should be recognized as ıving influence and standing and weight in this State. What better ·rvice could it render in the course of a quarter century than to have ·omulgated steadily that notion of appreciation of scientific methods and ·ientific spirit? It is worth more than papers. It is the ultimate ob- ·ct of this Academy. It is the highest service it can render the State ; a matter of public welfare and public education.

Now, that is very intangible, I realize, but I think it is an end worth ıinking about. (Applause.)

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Dr. C. L. Mees: It appears to me that the remarks I had prepared ›on being notified to speak have been stolen by those who have pre- ·ded me. It is an old Chinese saying that it is dangerous to stoop down ·en to fasten your shoe strings in your neighbor's melon patch. So there very little left for me to say.

I certainly am thoroughly in accord with all that has been said this orning, and by Dr. Coulter last evening, but there are one or two prac- cal things which come to my mind now. Dr. Coulter referred to the fact ıat we are in danger of dissipation. Owing to the fact that the number ' scientific workers in special lines in Indiana has increased very greatly ı the last two years, papers presented to the Academy have become more ıd more technical in narrow specialties and the number capable of discus- ng them or even following them as presented was necessarily small and in- ·rest correspondingly flagged. This condition led to the formation of half dozen or more of scientific societies made up of men especially interested ong narrow lines of scientific research, commanding the interest and at- ·ndance of those having common interest and drawing their attention ıd membership from the Academy. Now the question is whether the cademy cannot devise some plan by which the work of these various ›cieties could be co-ordinated and perhaps their meetings be arranged › occur about the same time as the Academy meeting. If the program f the Academy meeting could be somewhat shortened and the papers be

made of more general interest, they would serve the purpose, as Dr. Stone has just intimated, of developing the scientific spirit, and then let the different societies meet and discuss the technical papers they may have to offer. I merely offer this as a suggestion, and do not know whether it would be practical.

There is another suggestion which possibly might be worked out. The American Institute of Electrical Engineers has tried a somewhat similar plan, that is, to have scholars from the various colleges where more or less graduate work is being done, attend meetings, and thus give them an enthusiasm which contact alone will bring, and publish their papers, if worthy, and interest them in the work of the Academy later on.

These are some of the practical points that come to my mind in connection with the future plans of this Academy. I believe the danger is now that, unless the character of the activity of the society is somewhat changed, we will become a sort of body which exists upon paper and in lists of membership, rather than in active work.

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Mr. W. A. Cogshall (Bloomington): I have been very much interested in the statements during the last two days of the early work of the Academy—its early organization and membership, and in the large number of suggestions that have been made for the future of the Academy. I think most of these are good. It only remains to adopt some definite plans by which these suggestions can be put into something tangible. I do not know whether such plans can be worked out in the immediate future or not.

It seems to me the aim of this Academy is first to encourage scientific work among a good many who without the Academy would not do any such work. It does that to a certain extent. We have every year a long list of papers from men who do not belong to other scientific societies, and it is a good thing for them and a good thing for the State at large that these papers should be prepared and printed.

The other aim of the Academy, and which I believe to be the main one, is the bringing together of the scientific men of the State—not necessarily to hear the papers, as was very well said last night. I do not know that I should put the papers in quite so insignificant a place as was indicated, but we could well have the program the real excuse for meeting, and make that the frame-work of the whole thing. But I think a good

deal of the scientific benefit is lost or perhaps not realized, by having such a large number of papers of such short duration. To my mind it takes a man who is a good deal better than the average to prepare a paper of five or ten minutes in length, that has anything in it, and if that is all there is to the paper, I do not know that it is really worth while to read it. I believe the whole work of the Academy could be much better carried on if we did not try to crowd sixty or seventy papers into one short meeting.

With the great number of things that have come into life since this Academy was organized, it is not possible for us to give two or three days continuously to a meeting of this kind very often, and so we could not have sixty or seventy papers. But if we could have papers that are long enough to be beneficial, and put them into a shorter space of time, we could then devote more time to the social element of the meeting. I do not believe we get much social benefit from the meeting, as it only happens once a year. We come up here and meet a few men and go back home, and in the course of a few months we have forgotten who these men were and where they came from and what sort of work they are particularly interested in. I believe we should have meetings which would not be too scientific very much oftener than once a year, which would serve to bring the members of this Academy into closer touch with each other.

I would suggest that we have, if possible, some sort of Academy headquarters here in Indianapolis, and that once a month or once in two months, or once a quarter, as may seem advisable, notices be sent out to the members that there will be a meeting. Have not over one or two papers, that could be presented after a little dinner or lunch. I think this would be well worth while.

I was very much interested yesterday in the statements of the Librarian of the State, in regard to the new building that is proposed. If by any possibility that building could be obtained through appropriation from the Legislature, a permanent headquarters for the Indiana Academy could be secured, a most excellent place for carrying out some such idea. It would give us a place for our library, and it seems to me it would be a benefit to the Academy on every side. It would bring the whole scientific body of the State of Indiana together often enough to get acquainted and keep acquainted.

I believe that some sort of permanent headquarters, more frequent meetings and shorter meetings, would give us the best results in this State.

# BANQUET.

## FRIDAY EVENING, NOVEMBER 29, 1909.

DAVID W. DENNIS, Toastmaster.

SPEAKERS.

DAVID STARR JORDAN.
ALFRED SPRINGER.
GLENN CULBERTSON.
M. H. STUART.
JOHN M. COULTER.
GEORGE T. MOORE.
W. A. NOYES.
CHAS. W. GREENE.
B. W. EVERMANN.

MEMBERS AND THEIR FRIENDS PRESENT.

Andrews, F. M.
Bangs, E. H.
Barnard, H. E., and wife.
Barnhill, Dr. J. F., and wife.
Bennett, L. F.
Benton, G. W.
Bigney, A. J.
Bitting, Dr. A. W.
Bitting, Mrs. Katherine Golden.
Blanchard, W. M.
Blatchley, W. S.
Bodine, D.
Brayton, Dr. A. W.
Breeze, F. J.
Bross, Ernest.
Brossman, C.
Brown, D. C.
Brown, Hilton U.
Bruner, H. L.
Burrage, S.
Butler, A. W., and wife.
Bruce, E. M.
Carmen, E. K., Miss.
Cogshall, W. A.
Coulter, J. M.
Coulter, Stanley.
Cox, W. C.
Cox, U. O.
Culbertson, Glenn.
Daniels, L. E.
Deam, C. C.
Dennis, D. W.
Dillan, Miss F. E.
Dryer, C. R.
Dunn, J. P.
Earp, Dr. S. E.
Eigenmann, C. H.
Enders, H. E.
Evans, P. N.
Evermann, B. W.
Felver, W. P.
Foley, A. L.
Francis, J. R.
Gabel, J. D.
Golden, M. J.
Gottlieb, F. W.
Greene, C. W.
Greene, F. C.
Hadley, A. N.
Hankinson, T. L.
Hart, W. W.
Hathaway, A. S.
Hofer, G. N.
Hole, A. D.
Hyde, Roscoe.
Johnson, A. G.

Johnson, S.
Jordan, D. S.
Kenyon, A. M.
Kern, F. D.
King, R. M.
McBeth, W. A.
McBride, R. W.
Mees, C. L.
Millis, W. A.
Moenkhaus, W. J.
Montgomery, H. T.
Moore, G. T.
Moore, R. B.
Morrison, E.
Mowrer, F. K.
Noe, Fletcher M.
Noyes, W. A.
Pohlman, A. G.
Potter, Dr. Theodore.
Ransom, J. H.
Rettger, L. J.
Smith, E. R.
Springer, Dr. A.
Stoddard, Dr. S. P.
Stoltz, Charles.
Stoltz, Charles, Jr.
Stone, W. E.
Stuart, M. H.
Swift, L. B.
Taylor, F. B.
Thomas, M. B.
Thompson, Willis S.
Transeau, E. N.
Turner, W. P.
Van Gorder, W. B.
Waterman, Dr. L. D.
Weems, M. L.
Williamson, E. B.
Woodhams, John W.
Woollen, W. W.
Wright, John S., and wife.
Young, J. P.
Zimmer, H. E.

Dr. A. L. Foley: It seems to me the Program Committee has shown ırticularly good judgment in the program it has provided, and in no way ıs that good judgment been better shown than in the selection of the oastmaster for this evening.

There is no man in Indiana who has had more influence upon the ·achers of the State, upon the schools of the State; there is no man who as been closer to the hearts of his pupils. There is no man who has had ıore to do with the development of science in Indiana than has Professor avid W. Dennis, of Earlham College, who will preside. (Applause.)

Prof. David W. Dennis: I am sure, ladies and gentlemen, that I ish more than any of you possibly can that all of that was true.

In science we have many of us been very lately instructed by an emıent Hoosier that nothing at all is settled, and I came to the conclusion ıis morning when recapitulation went overboard that perhaps it is so. ut the records of the Indiana Academy of Science would furnish many xceptions to this rule. During these twenty-five years we have been ettling a considerable number of questions; some of these have been ettled so effectually that they have never come up again. For instance,

many years ago—so many that I have forgotten the exact date—Dr. Jordan presented a discussion on "Fishing all the way from the Amazon to Greenland," and he said that the number of vertebræ in the fishes of the same species always increases with the latitude in which the fish is caught. He suggested that he knew no reason for it unless perhaps it is that life expresses itself in more vigorous terms at the pole than at the equator. But Prof. T. C. Mendenhall offered a theory that was received with much applause, and that everyone thought was right. He said the North always had more backbone than the South, anyway. (Laughter). So that is one question we have settled.

I remember also that twenty-four years ago our botanist presented to us what he was pleased to call a very important question. Several others have been presented that were more or less important, but this was really important, and it was, in general terms, the development of life from the plasmodium to the oak. He referred to the fact that mushrooms—I tried to get his exact words, but we did not publish in those days, so this is as I remember it—that mushrooms "are degenerates, mere driftwood cast up by the waves of life's ocean." Incidentally this idea was illustrated by another journey parallel to it, from the Amœba by way of the ascidian to man. In the discussion which followed, our zoölogist arose and said the ascidians "are degenerates, mere driftwood cast up by the waves of life's ocean;" so the status of the mushroom and the ascidian was settled.

We really took up some serious questions. I remember that Professor Waldo in a wide discussion of mathematical questions, had a good deal to say about parabolas, hyperbolas, asymtotes and other similar things; Professor Neff then followed with a paper dealing with the refinements of organic chemistry, which he illustrated with what appeared to be colored chalk; all of us were lost some of the time and some of us were lost all the time for some hours. This was followed by a glowing vision of creation from a Darwinian standpoint. It was an interesting occasion; we all understood and took on a benevolent expression. But the many things we used to teach that are discarded now were useful in their day. Carlyle says somewhere that the present time is "child and heir of all the past and parent of all the future," and I could not help thinking this morning when Prof. Coulter was talking, that as one after another these theories have been set aside, there has been a reason for the existence of

each one, and it has called into existence something that is better than it was itself. Our criticism is constructive.

I believe scientific men—or at least if you will make it a little broader than that, the school-master today is the priest of today; and he is going to be the priest of the future. There were some questions submitted to the children of the schools in one of our cities; one of them was, "Where is Heaven?" In the answers one of the pupils (it was a girl, so there could not have been any malice in it) said that Heaven was said to be above the clouds, but she added that physical geography teaches that the atmosphere is only about forty-five miles high, and that even a very few miles up it is probably not possible for anybody to live, so Heaven could not be there at all. Whatever that child may have thought that was wrong or inadequate about Heaven, it is clear that she believed the things her teacher had taught her about the air. He, instead of her minister—if she had one—was her priest.

I happened to be present at the inception of this Society after Amos Butler brought it to us, and of course it would be very easy to continue these reminiscences; but that is not what the committee asked me to do, and I do not intend to do it. But this Society has been a great help to me and to all of us, not only in its meetings, but in the rambles we have had over all parts of Indiana in our Spring meetings. We went out to Fort Quiatanon and hunted beads the Indians had lost at the old trading post and were as happy when we found one as the Indians were sorry when they lost it; we have gone over the whole State getting acquainted with whatever of interest it had to offer. Even at the very first meeting down at Brookville, the home of the Academy, we went swimming, and naturally got acquainted with ourselves; saw ourselves in a sense in which others did not very often see us. (Laughter). These social occasions have been the best part to me, after all is said, of the meetings of the Academy from the beginning until now.

I have the pleasant and easy task of introducing first a man who needs no presentation to scientific men anywhere; a man who needs no title, but whose titles are so numerous that there would not be time to read them. He is an investigator and a teacher, was for a time the premier of Indiana teachers. He is an author to whom science owes much and man owes more; the man for whom the river Jordan was named. (Laughter). Dr. David Starr Jordan, President of Leland Stanford University. (Applause.)

Dr. David Starr Jordan: Mr. Toastmaster and President, Members of the Academy, Ladies and Gentlemen: It is a pretty hard thing to respond, impromptu, to all that. I only hope there is some of it that is not true. It is a very great pleasure to me to get back here, and yet that pleasure is not unmixed with a certain kind of pain. I was just remarking to Dr. Coulter that in the "fierce democracy" of this Indiana Academy "there was a Brutus once who would have brooked the eternal devil to take his seat in Rome" as easily as he would have sat for dinner in a dress-suit. But to see this "fierce democracy" in the brook at Brookville—it gives me a certain sense of pain. (Laughter.) And speaking of Brutus calls to my mind Marc Anthony, and I remember an occasion when a gentleman was called upon to speak, and he had only one speech which he said over and over, and just before going in he asked if anyone could give him the address of Marc Anthony. A friend said, "You know Anthony's style of life and the people he associated with; I should think his address would be at the same old place." (Laughter.)

I saw a statement not long ago by Henry Fairfield Osborn, that he did not think it possible for an American University to produce a Darwin, and the reasons he gave were that first, he—that is, the student nowadays—did not have to contend in his early life with something that was distasteful to him, as Darwin did; second, scientific men do not have the appreciation here that scientific men do in England; and third, that the scientific men of this country do not have the leisure to become such as Darwin was. It does not seem to me that these reasons are very good. I do not think, perhaps Darwin did not think, that any appreciable part of his greatness was due to the work in the University which he said was incredibly dull, and which led him to feel that he would never read a book on a certain subject afterwards. And as for appreciation in this country, you have just heard how scientific men are appreciated in Indiana, and it is even so everywhere we go. And so we have this kind of treatment, in America, whereas Darwin was named "gas" by his fellow-students, because he confined himself more or less to chemical experiments. And as for leisure, I know a great many scientific men of leisure who have never made any pretense to being Darwins on that account. It seems to me that Darwin was first made by heredity. There will never be another; you cannot get a man of high scientific rank and quality unless heredity starts the thing. You have to get the right kind of stock. There is no reason why the right kind of stock should not be found in Indiana,

for there is such an amount of genius in this State that it spills over into all the other States. California is full of it that has been borrowed from Indiana, and so with the other States. The first thing, then, is heredity. The second thing is to be "up against it." We read in history that Darwin went to see horse races and watched them very closely; that he was interested in the beetles of England and gathered beetles in season and out of season. In other words, with all the scientific training a student gets he should be brought right up against nature; against the things that do not lie if you listen to what they have to say. Then the third thing. We read in the various historical sketches of Darwin that he "walked with Henslow," a man with enthusiasm, and this enthusiasm was passed from the teacher to him. I take it, then, that the making of a great man of science rests on these three things, and I do not think the other things have anything to do with it. I notice a man will do just as much when he has not any time, as he will when he has all the time there is.

Now, I think we have these elements to a greater or less extent in our modern Universities. Of course, heredity is not included, but the second element, that of coming up against it, is more or less within the power of every institution now. There was a time when institutions prided themselves that they did not let the students come up against any scientific knowledge. There was a time when the University teacher—an A. B. —was more interested in the song of the oriole than the students in his classes. But the Universities have recognized that defect. Now, the third element, "walking with Henslow." Jacques Loeb, of the University of Chicago, told me awhile ago that he received a very enthusiastic letter from a young man who said he wanted above all things to study the origin of life, and that he wanted above all things to study under Loeb and enjoy his fellowship. Then Loeb wrote back that, unfortunately, he had decided to go to California, and the young man wrote back: "Will you kindly turn my letter over to your successor?"

Now, to a large degree, young men are training themselves wrong. Instead of "walking with Henslow," they are going where they are hired for $200 to $500 a year. They are a bar to scientific research, for what professor can teach his students to do a thing which he cannot do himself? You may remember in the last number of the Atlantic Monthly, an article by Professor Showerman of the University of Wisconsin. The professor had worked for some time on the prefixes in P, of Plautus, he was then working on the suffixes in S, of Seneca, to be followed by the termi-

nations in T of Terence. The point I want to get at is that this is not advanced work, and the student will not gain enthusiasm. I do not think we ought to mistake for advanced study this very elemental work, the things that are of no consequence, and just so far as we allow our young men to do this elementary work, so far will we find them going out as teachers without enthusiasm, and saying that it is impossible in this country ever to see another Darwin. (Applause.)

Mr. Dennis: The next speaker is a member of the Academy, and has been for eighteen years. He came to us from the neighboring State of Ohio, and we expect him this evening to bring the greetings of his native State to the Academy. He is the gentleman who in his earlier scientific career invented the torsion balance. At the present time his specialty is fermentation.

Dr. Alfred Springer, of Cincinnati.

Dr. Alfred Springer: Mr. Toastmaster, Ladies and Gentlemen: It certainly affords me great pleasure to be here with you this evening, and no little gratification to be permitted to address a body of men, many of whom have carved their names deeply in the records of scientific achievement. The achievements of those of you who have remained at home have become household words, and the fame of those who have left the State to spread such brightness as only science can convey, has loomed up conspicuously among many brilliant lights. Twenty years ago the American Association for the Advancement of Science, in looking over its list of eligible candidates, selected from your members T. C. Mendenhall as the man worthy to represent it as President. Chairmen for the various sections of the American Association have frequently been selected from the Indiana Academy on account of the good work they have done. As for the General Secretary of the American Association, where could a better and more popular one be found than in our own Amos. W. Butler? He graced that position in 1892, and ornithologically speaking, he was a "bird." (Laughter.) This year the American Association for the Advancement of Science has honored itself in selecting one of your past presidents for its President. No one who knows Dr. David Starr Jordan doubts but that he will add additional lustre to its already bright pages.

Permit me, as a delegate from the Cincinnati Section of the American Chemical Society, to congratulate you on the twenty-five years of your existence, and to bespeak for the future, if such a thing be possible, greater success than in the past. (Applause.)

PROFESSOR DENNIS: The program committee wished a man to speak for the small college, and it has asked Professor Culbertson to do this. He was President of this Academy last year, and it is a fact that he has been a member of the Indiana State Legislature. I cannot understand how it came to pass, but will leave that for him to explain—it is true. If he occupies six minutes' time, he has obtained for us through the Legislature $100 a minute every year for all of that time, and I think he will be entitled to at least that much. Prof. Glenn Culbertson, of Hanover College.

PROFESSOR GLENN CULBERTSON: Mr. Toastmaster, Ladies and Gentlemen: I shall not attempt to explain how I came to the Legislature. I enjoyed the experience very much, but I do not know that I shall care to go through it again, so you had better be looking up another candidate if you want the appropriation continued two years longer. I was very much pleased to hear the expression this morning, but there really was not very much difficulty in getting the appropriation. And I want to say this in regard to that appropriation, that I did not do anything that was against my conscience in attempting to get it. If I had not felt that there were good papers presented to this Academy every year that ought to be published in its report, I should not have worked for this $600 additional appropriation.

My subject is "The small college in its relation to the Academy of Science." I think by going back twenty-five years in the history of the Indiana Academy of Science, every college in the State would come in that class. Since then, of course, some of them have moved forward into a higher class. I have been a member of the Academy for some fifteen or sixteen years, and it has been a great pleasure to come up here year after year to hear the papers read and the discussions entered into. They certainly have been an inspiration to me, and I take it they have to every man in a small institution in Indiana. We are spread out over a considerable territory, and we have a great deal of work to do. Dr. Jordan says that the more work a man has to do the more he will do, but it is true that if we have a great deal of work along different lines we do not have time to put in special work in preparing such papers as we have heard here year after year; nevertheless we have all done our part. Of course, we of the smaller colleges rather envy a good many of the teachers in larger institutions because of their ability and opportunity to pursue their work along certain lines, but there are compensations. We get a broader grasp

of things in a certain way, and we have certain relationships that are very pleasant to us. I will admit that with some of the papers, all I can do is to look wise, but I have received a great benefit from a good many of them, and have gone back home resolved to understand more fully these things that are brought to our notice.

So far as the work of the small institutions of the State is concerned you have only to look at the program to see that the small institutions have done their share in producing the scientific men that have been an honor to Indiana. We are very proud of them today.

I want to thank you for listening to the words I have spoken, but I think you can listen to better advantage to those who are to follow me.

PROFESSOR DENNIS: Mr. Milo H. Stuart, of the Manual Training High School, has been requested by the committee to speak on the subject of High Schools. He was principal of the High School at St. Paul before coming here, and is certainly as well qualified to speak from that standpoint as any member of the Academy.

PROFESSOR MILO H. STUART: Mr. Toastmaster, Ladies and Gentlemen: It is easy to see, in the splendid addresses to which we have been listening, why the Academy has endeared itself to the people of Indiana. I would be pleased to add other reminiscences if I could do so, but I am too late a recruit to make any contribution along that line.

Coming from the High School field, I naturally think of the work of the Academy from that standpoint. As we have heard these inspiring addresses today I have been thinking how fine it would be if every science teacher of the State of Indiana could have been induced to come to this fount of inspiration. I believe he would have gone back to his classes with fresh ardor.

We all remember when we left our Universities and got into original work, how great a pleasure it was to feel that we had contributed just a little to the volume of knowledge. The compensation that comes from that kind of labor is certainly very great, and it seems to me if the teachers of the State could come into touch with the people who are doing it they would feel their load a great deal lighter. I know they would take back to their boys and girls inspiration that would fast make scientists out of them.

This Academy of Science marks its twenty-fifth milestone today, and its face is set toward the golden anniversary. I am reminded of the story

of the Irishman who said he wished he knew just the spot where he would die. His brother asked him what he wanted to know that for, and he said if he knew the exact spot, he would spend the rest of his life keeping away from it. So I think the Indiana Academy of Science, through some of its officials, must have discovered the spot where it might die, and started in the opposite direction, and we are twenty-five years removed from that place tonight.

That leads me (with apologies to Tennyson) to conclude by saying, that

Scientists may come and scientists may go,
But the Academy goes on forever.

(Applause.)

PROFESSOR DENNIS: Every word I said in introducing Dr. Jordan is true of the next speaker; every teacher in the state would forgive me for saying that after Dr. Jordan left us he became our premier. There was, however, one difference. Dr. Jordan, as President of the State University, had for his rule a motto "Die Luft der Freiheit weht."

The students hardly knew what this meant but finally concluded it was "No smoking in the buildings." Prof. Coulter succeeded Jordan and the first day he smoked in the office. (He sometimes smoked in those days.) The students made a bonfire of their best hats:—they had had but one rule and now they had none. Prof. John M. Coulter, of the University of Chicago.

DR. JOHN M. COULTER: Mr. Toastmaster and Friends: All these ancient and new members of the Academy, who have spoken, have about exhausted the subjects, and I hardly know where to find myself. One thing I had in mind when Dr. Jordan was suggesting that heredity perhaps determined in the first place whether a man was going to do anything or not, and that things that followed were more or less auxiliary. I remember to have heard Dr. Wiley some years ago raise the question why there were so many scientific men in this State as well as men who had achieved more or less distinction in other callings. He answered it then to his own satisfaction. I have never seen it tested, but he concluded that the men in Indiana who had made their mark in science or in any of the other professions were the men whose early life had been spent in the most forbidding parts of the State from an agricultural point of view, and that there was nothing to become interested in except education. Just how many scientific men were lined up in this roll-call, I do not know, but

when this State is unable to produce anything else, it can produce distinguished men.

I suppose a charter member is expected to be more or less reminiscent, and there are two or three things that the other speakers have left unmentioned.

In its early days, twenty-five years ago, this Academy meant a great deal to those who were members, and for two or three reasons. I think Dr. Jordan and Amos Butler, for example, will bear me out in this. In the first place this State science was comparatively new; it was new to us, new to the State, and new to the country. We came together as a set of young men who were interested in a new thing with a sort of fine enthusiasm with respect to the unknown that is found everywhere. In the next place, the instruction in science, with which all of us were more or less concerned, was just as new. It was even newer, because in those days the position of science in the colleges we represented was more or less doubtful and some of the things we taught were often looked at askance. The whole situation in the matter of scientific instruction was in its very beginnings. This also gave us a fine enthusiasm, a sort of feeling of comradeship in a campaign. We felt the need of companionship, and we found it in the Academy. We would come here from our various colleges, full of enthusiasm, and talk over the problems, and this formed a nucleus of sentiment, an esprit du corps that first developed among us, and which has since developed and given to the Academy the place it now occupies in the State. I think perhaps a feature that sustained us, and that made as much for the solidarity of this Academy as any other, was that one of our first campaigns in the State was educational. Science was fighting for its life, for a place in the colleges. There was another association that met at the same time in Indianapolis, known as the "College Association," and one of the functions of the Academy was to lay plans to assault that "College Association." I remember distinctly one of the things we had to combat. There was a tendency to antagonize the intellectual tastes of the students in those days, and one of the old professors said he thought that the very thing a student needed was the thing he disliked the most. If he disliked mathematics, *make* him take it; if he disliked Greek, *make* him take it. That was one of the educational slogans at that day,—every student needs what he dislikes. I have an idea that no one thing could have brought us closer together in our community of interest than the discussion of these educational questions.

But today you are threatened by a danger that we did not encounter. Every interest brought us together; every impulse was to come here to meet friends and associates. Now the tendency is rather the other way. We are becoming more and more independent; we are becoming more and more narrow; and we are in greater danger of working apart than ever before in our history. Many fine men are growing up who have the very smallest amount of interest in anything that is going on outside of their own field, and as a consequence there is a tendency to segregation which I feel to be a thing that must be combated.

There are two dangers I wish to call to your attention, two dangers that reunions of this kind will help to correct. One of these is the matter of personality, the kind of personality that can only be developed in contact with men, that cannot be developed in connection with one's own theories and one's own way of looking at things. It is the kind of personality that influences men and is sympathetic with them, and can only be obtained by knowing men, thus gaining a very much wider range than is possible within the limits of one's own field. It seems to me that is one of the striking features that ought to be thought of in connection with this Academy. Frankly, I think that papers are relatively very unimportant things. I never saw very much inspiration in papers. The inspiration comes from association with men, and that is the thing to cultivate—this opportunity to associate one with another.

The other thing we are in danger of losing sight of, and which this Academy can correct, is the tendency to become narrow in our vision and lose our perspective of the whole general field, not only of science but also of education. You will find that as scientific men become less and less interested in other fields of work, as they grind their own grooves deeper and deeper, they become less and less effective as teachers and less and less influential with their students. You will find men with broad outlook, clear and wide vision, men with sympathy—and men can only get these things by coming in contact with larger fields than their own—are the men who win with students.

These two things we want in these days, men with sympathetic personality, with a broad view over science in general, with an appreciation of the work of others, and with larger view of education as well. I hear that the art of teaching is disappearing. It seems to me that the fine enthusiasm which a teacher must impart to his student, is in danger of dis-

appearing from our scientific laboratories, which are too much in danger of becoming mere factories.

Your number is so small that you can really know one another and can know the work that is being done by one another, and that is just the sort of thing you need. You do not need to come here for training in science; the Academy is no place for training, it is for association and personal inspiration. (Applause.)

PROFESSOR DENNIS: Ladies and Gentlemen: Some years ago "plankton" got into the reservoir of our waterworks at Richmond, and we were a unit that we could not get along with it there any longer, and when we set out to procure a remedy we found that such a remedy had been worked out by a member of this Academy, and this man is the one I will now call on to speak. He is a graduate of Wabash College. He is the inventor of a means of culture for the nitrifying bacteria of the soil, which invention he did not patent, but gave to the American people. This puts us all under obligations to him.

Mr. George T. Moore, of the Botanical Gardens of St. Louis. (Applause.)

In his response Mr. Moore called attention in a humorous way, to some of the advantages of scientific knowledge, and in conclusion presented the greetings and best wishes of the St. Louis Academy of Science and the Missouri Botanical Garden.

PROFESSOR DENNIS: A number of telegrams and letters have been received since the adjournment, and I will ask Prof. Butler to read them now.

(The letter of Dr. Wiley is appended as it was the basis for action in the closing session on Saturday morning).

WASHINGTON, D. C., Nov. 22, 1909.

Mr. A. W. Butler, Indianapolis, Indiana.

Dear Mr. Butler—I have received from you and other members of the Academy of Science, cordial invitations to be present at the 25th anniversary meeting, November 25th-27th, 1909. Should I consult my personal desires I would surely accept the invitation. Just at this time, however, two extremely important cases are in preparation for trial before the United States courts, (1) the use of borax in foods, and (2) the use of peroxides of nitrogen in bleached flour. I am compelled to give every moment of my time to the preparation for these cases, the first one of which will be called in the federal court in Peoria on the 8th of December. I

therefore am constrained by reason of these public duties to decline the invitation to be present at the meeting of the Academy of Science. I want to say, however, just one word to the members of the Academy, and that is a word of congratulation on the work which has been accomplished by the Indiana Academy of Science in the quarter of a century which has passed.

I do not believe that any state association in the country of a similar character has accomplished so much, nor has brought together a band of men more devoted to research, more single in purpose and more enthusiastic in the pursuit of scientific truth. Many of the members of the Association have from time to time gone out into other parts of the country to pursue their work in other States. Not one of them, I believe, has lost his love for the Academy nor parted with his devotion to its cause and welfare.

I have been reading lately some of the early history of Indiana in its political and literary development. I should like to suggest that some member of the Society, before the data are scattered and while it is still possible to derive from the mouths of living witnesses important facts, should write the history of early scientific education in Indiana, beginning with the work of the Owens at New Harmony, almost a hundred years ago, and bringing it up to the era of the establishment of the new science, say about to 1875, or 1880. To write the work of scientific research of Indiana in the last twenty-five years would be too much of an undertaking for any one man, but the greatest interest would attach to a history of the scientific development of Indiana from the time of its beginning, or a little after, up to the date which I have mentioned above. I feel sure that there are enthusiastic and industrious members of the Society who would undertake to do this, either by collaboration or by helping some one who would voluntarily assume the burden of the work. Scientific men of Indiana whose experience goes back of 1875 might contribute personal recollections of scientific development which would prove of intense interest. The scientific work of the early colleges of Indiana is worth the most careful study and would make interesting chapters in the history of those days when the study of science was not considered to be a requisite for a liberal education as it is at the present time. The story of the work of such men as R. T. Brown, E. T. Cox, Dr. Levette, John Coburn, and others of that class would make most interesting contributions to a work of this description. At the present time when there is so much interest in the early political and literary history of the State it seems to me the scientific history should not be neglected.

I had hoped to present and read some paper of a scientific character at the meeting, but as this is not to be, I should like to present in lieu thereof this suggestion, which I hope will be given due consideration, because if it can be carried out it will be historical as well as a scientific

work which will prove of immeasurable interest in the near future, if not at the present time.

Let me close with the hope that this meeting may be all its promoters have intended it should be—a feast not only of science but of friendship—that it may result in the stronger cementation of the bonds which hold the love of the loyal Hoosiers firmly to the State, and excite a pride in the scientific work of Indiana which may rival that which so justly exists respecting its literary accomplishments.

Sincerely,

H. W. Wiley.

Professor Dennis: The Committee wishes to honor many more members of the Academy by asking them to speak to you this evening, but on account of the lateness of the hour we will have to restrict the number. I will now call on our old comrade, Prof. W. A. Noyes, of the University of Illinois.

Professor W. A. Noyes: Mr. Toastmaster, Ladies and Gentlemen: I have been resting very quietly and easily all the evening, not seeing my name on the program, and not having the slightest hint that I would be called upon. It is surely a very great pleasure to be here, and I would like to say just a word about the old times when the Academy started. I believe I was one of the charter members, and one of the things I remember of that time was the discussion in regard to the name that we should adopt. It was finally agreed, if I remember correctly on the recommendation of Dr. Jordan, that we should call it the Indiana Academy of Science, not the Indiana Academy of Sciences. I think that in his mind and in ours, as we selected that name, was the thought that after all there should be but one science, which is all-embracing, and I feel that as one of the ideals of the Academy it has been of the greatest value to us. As we come together in these meetings of the Indiana Academy, we feel that no matter how separated our lines of work may be, how different—so different sometimes that we can understand but little of each other's language—yet after all we are simply working in different parts of one great whole of scientific knowledge, and that it is our place to look at our part, our field, as merely one part of the whole, all parts of which may in some way or other touch our own. And this opportunity of seeing, of catching even a little glimpse of this work that is so far removed, perhaps, from our own, and the acquaintance of these men who are working in the different fields, is, it seems to me, one of the features of greatest value in these friendships and associations which we have made here in this Academy.

PROFESSOR DENNIS: We shall now hear from Professor Charles W. Greene, of the Uinversity of Missouri.

PROF. CHARLES W. GREENE: Mr. Toastmaster: It seems rather unfortunate that a man such as I, of no ability as a speaker, should be called upon, but I will do the best I can to express the feeling of enthusiasm and encouragement this meeting has given me. It has been a great pleasure to meet so many friends and to recall old times when the Academy first began, the time when at DePauw, through the genial personality of Professor Jenkins, we began to catch the scientific spirit. I remember my first meeting with the Academy was at Greencastle. We went out on a field excursion and we younger men were brought into intimate contact with the stimulating personal enthusiasm which always characterizes Indiana scientists.

I think one of the features of this meeting has been the showing of the great tolerance that has been developed in our scientific lines of thought. Dr. Coulter showed us that this morning. It is certainly very encouraging to the physiologist to learn that in the life of the plant, in its growth from the plasmodium, it is not predestined to go through any fixed and inflexible schedule of development. I felt at the time that probably the calm cold conservatism of morphology was yielding to the seductive charms of physiology as expressed in environment, that a new era in botany was still possiblie to us. That was not the old botany but a glimpse of the new.

PROFESSOR DENNIS: Dr. Evermann for a long time a member of the Academy is with us and will tell us what members of the Academy are doing in Washington. He represents the Atlantic here as Dr. Jordan the Pacific. He gave us last night an account of a fishing trip to the "Tiptop of the United States" but he did not produce his "records or his instruments" or even his fishes; he gave us only fish stories. Perhaps he has he real article with him this evening. Dr. Barton Warren Evermann of he U. S. Fish Commission.

DR. BARTON W. EVERMANN: Mr. Toastmaster and Amos Butler—or he Indiana Academy—they mean the same thing. I have been looking at this program ever since I came into the room, and I notice what my friend, Dr. Coulter, also noticed, and mentioned in his remarks—the toast immediately following my name, which I fear bears some relation to what I have already said or what I may say in this meeting. "Lord, Lord, how

this world is given to lying!" But I am glad Dr. Coulter noticed this and put in a disclaimer, thus relieving me to some extent of the suspicion that my fish stories were the only ones in mind.

I would like to say a word regarding those of the Indiana Academy who are now in Washington, and to tell you something of what they are doing. I noticed, perhaps you noticed, in a recent magazine, a long article on "The Plunderers of Washington." There were a dozen or more of them, and I am glad to say to you that there was not among these plunderers who were pictured in this article, any Washington member of the Indiana Academy. We all escaped that distinction at least! I think I can also say that no member of the Indiana Academy in Washington has been seriously involved in the Cook-Peary controversy. We have kept clear of that, also. If there is anything the Indianian learned long ago, it is to take care of himself and not to get into embarrassing situations needlessly. So in this case the members of the Indiana Academy have read the very interesting article by George Kennan in the Outlook which proved very conclusively that Dr. Cook did not have more than one-tenth of the pemmican necessary to enable him and his dogs to reach the North Pole. They took that for what it was worth, and waited for something further. Then in another magazine some man from the West had the whole thing figured out, showing that Kennan had Cook's dogs continuing to eat pemmican at the rate of a pound a day even after they were dead and the Indiana Academy people in Washington hope Kennan may be able to explain why and how they did such an unusual thing.

Several of your friends in Washington are engaged in very interesting work which has an important bearing upon matters in this State. Our good friend, Dr. Wiley, the most distinguished Washington member from this State, is still continuing his pure food work and trying to answer the question "What is whisky?" Dr. Hay, a former President of the Academy, and now in Washington, is trying to determine, no doubt for the benefit of the Academy, the age of the Ceratops beds in Wyoming, Idaho and Montana.

One matter that I think will be of some interest to you here in the Mississippi Valley, is that the Bureau of Fisheries is establishing a biological station at Fairport, Iowa, in the interest of pearls and the pearl button industry, a matter which will appeal to the ladies. There was established some few years ago a small button factory at Davenport. A

German came over and saw the great numbers of mussels in the Mississippi River, and thought they might make good buttons. He began experimenting and soon demonstrated that they were well adapted to this purpose, and now more than fifty thousand tons of these fresh-water mussels are used annually. This is a greater quantity than natural production can supply. The supply, of course, cannot keep up. Fifty thousand tons a year will soon use up the supply. The Bureau of Fisheries realized the possibility of an early depletion of the supply of shells and arranged with Professors Lefevre and Curtis of the University of Missouri to experiment and see if they could not develop a method for the artificial propagation of fresh-water mussels; and they have succeeded, so that the propagation of fresh-water mussels will soon be an easy proposition. Congress made an appropriation for a biological station in which these experiments may be carried forward. We have acquired sixty-five acres of land at Fairport, and the construction work is now going on at that place. It is the ambition of those who are particularly interested in that station to see there a station which will appeal to every biologist in the Mississippi basin. We want to make it a fresh-water biological station where any biologist of the Mississippi Valley or elsewhere may go and find the facilities and material for the study of any fresh-water biological problem in which he is interested; and the Bureau of Fisheries not only hopes you may avail yourselves of the advantage of the station when completed but most cordially invites you to do so.

Again on behalf of the Washington contingent I extend greetings to the Indiana Academy of Science. I thank you.

PROFESSOR DENNIS: I hope you will permit me to take another minute. Reference has been made again and again to the large number of splendid men who have gone out from this Academy. It would be equally proper to refer to the large number of valuable men who have come into the Academy. Reference was made this morning by Mr. William Watson Woollen to the fact that the Audubon Society was an offspring of this Academy. I am sure the mother of that Society was necessity, and the father of that Society as well as of this was Amos Butler. I ask now that the Academy stand, and drink the health, in cold water, of Amos Butler, the father of the Indiana Academy of Science. (Applause.)

MINUTES OF THE TWENTY-FIFTH
ANNUAL MEETING

# diana Academy of Science

CLAYPOOL HOTEL, INDIANAPOLIS, INDIANA,
Nov. 25, 26, 27, 1909.

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*Friday Morning, November 26, 1909.*

eeting called to order by the President, Dr. A. L. Foley.

eading of the minutes dispensed with.

R. FOLEY: We will now have the minutes of the Executive session t evening.

SSISTANT SECRETARY BIGNEY: The Indiana Academy of Science t the Claypool Hotel at four p. m., November 25th. Eleven members present and several visiting members of the Academy.

embers present were: A. L. Foley, President; J. H. Ransom, Secre- A. J. Bigney, Assistant Secretary; Robert Hassler; John S. Wright; L. Mees; W. S. Blatchley; M. B. Thomas; C. H. Eigenmann; A. W. r; D. S. Jordan.

L. Foley, President of the Academy, in the chair.

he report of the Committee on the 25th meeting, by A. W. Butler, as d on program, with several additional papers, was read.

. W. Benton, J. S. Wright and J. W. Woodhams reported that all for the banquet had been made.

Membership Committee made no report. Report of State Library iittee was made by J. S. Wright. He stated that the Proceedings of cademy were being cared for in good order and that many volumes een bound.

No report from Committee on Weeds and Diseases.

No report from Directors of Biological Survey.

No report from Committee on Relations to the State.

Committee on Distribution of Proceedings reported through J. S. Wright. All work had been performed.

Editorial Committee, by H. L. Bruner, reported work done as ordered.

Report of Secretary on non-resident list was taken up. On motion it was decided to place only those members on the non-resident list who had done work of marked credit to the Academy. The list was passed on by the Executive Committee.

Deaths of Dr. Gray and W. H. Ragan reported. Committee on Resolutions appointed, consisting of C. L. Mees, A. W. Butler and G. W. Benton.

Bills of expense were reported by A. W. Butler. They were referred to Auditing Committee.

Foreign Exchange list ordered to be revised and printed in next report.

Summer meeting to be passed on tomorrow.

Committee on Fellows also to consider a list of Honorary Fellows.

It was voted to place $25.00 at the disposal of the Secretary for his official duties.

Resolution from California Academy of Science read.

Dr. Jordan extended greeting from the California Academy of Science, and thanks for books.

Committee of two on Fellows was ordered to be appointed by Academy.

Motion that the chairmen of Committees be retained, committees to be filled by chairmen.

Auditing, Membership, Program and Nominating Committees not to be covered by previous motion.

On motion G. W. Benton was chosen as another Assistant Secretary.

Adjourned.

J. H. RANSOM, Secretary.

A. J. BIGNEY, Assistant Secretary.

(Report adopted as read.)

Dr. Foley: I will now call on Mr. A. W. Butler to make a statement in regard to this meeting of the Academy.

Mr. A. W. Butler: Mr. Chairman, and Members of the Academy: The program as printed, and which I suppose the most of you have in

your hands, has on it a list of sixty-three papers. There are six additional papers which have been added. One of these, a paper by Prof. M. B. Thomas, was omitted from the original list. The additions are as follows:

"The Wood Lot," M. B. Thomas.

"The Nasal Muscles of Vertebrates," H. L. Bruner.

"Streamers that Show Reversal of Curvature in the Corona of 1893," J. A. Miller.

"On a New Complex Copper Cyanogen Compound," A. R. Middleton.

"Determination of Endothermic Gases by Combustion," A. R. Middleton.

"That Erroneous Hiawatha," A. B. Reagan.

This brings the number of papers up to sixty-nine.

At the conclusion of the business of the meeting there will be responses from other State societies, some six or eight in number.

The program as printed indicates a banquet this evening, to which attention has been called, and the program for which will be announced later.

The program for tomorrow morning is also printed here, including four principal addresses, and suggestions as to plans for the Academy.

I want to say in behalf of the Committee on the Twenty-fifth Anniversary that we have been very much gratified by the interest that has been taken by the educational and scientific societies throughout the State. The Indiana Medical Association, the Historical Society, the Teachers' Association, and a number of other associations have by formal resolution recognized this twenty-fifth meeting, and several of them have appointed delegates to attend the meeting.

I would also like to call attention to the fact that we have had a very large number of congratulatory letters on the period we have arrived at in the history of this Society, and there are three I would like to call attention to. One is from one of the ex-Presidents whom we always delighted to honor, Mr. T. C. Mendenhall. He is at present in Europe in search of health, and as he cannot be present, sends his congratulations. Also a letter from Professor Goss, of the University of Illinois, who had expected to be present until he found that this date is the same as that of the dedication of their new Physics building, so he could not come. Also one from Prof. Kingsley, of Tufts College, Mass. These three letters are particularly earnest and cordial in their words of greeting.

We hope you will find everything arranged for your comfort and convenience, and beg to assure you that if anything has been overlooked or if there is anything you do not like in connection with the arrangements, we are sorry that such is the case. The Committee tried to do its best. (Applause.)

Dr. Foley: I will now call for reports from the different standing committees.

Program Committee, Mr. W. J. Moenkhaus, chairman: (This report included in the statement of Mr. Butler.)

Membership Committee:

(Moved and seconded that the Secretary cast the ballot of the Academy for the names read. Carried, and persons declared members upon signing of the Constitution and payment of dues.)

Treasurer's report, Mr. W. A. McBeth, Treasurer:

To the Indiana Academy of Science:

| | | |
|---|---|---|
| On hands, last report | $424 39 | |
| Received dues and fees for 1909 | 95 50 | |
| | | $519 89 |
| Expended as per receipts and vouchers | | 118 67 |
| Balance on hand | | $401 22 |

The papers and vouchers are ready for the Auditing Committee.

W. A. McBETH, Treasurer.

State Library Committee, J. S. Wright, chairman: (Postponed until later, when State Librarian Brown will make the report.)

Committee on Restriction of Weeds and Diseases: No report.

Directors of Bioligical Survey: No report.

Relations of Academy to the State: No report.

Distributions of Proceedings, J. S. Wright, chairman:

Mr. Wright: There is no special report to make. The Committee has the work in hand. We are now engaged in compiling a domestic exchange list.

Committee on Election of Fellows: Passed.

Report of Advertising Committee: (Included in statement of Mr. Butler.)

**Report of Editor:**

MR. H. L. BRUNER: The Proceedings for 1908 were published in the usual form. Each contributing author also received one hundred free reprints of his own article. (No reprints of abstracts were furnished.) The financial part of my report is as follows:

| | | |
|---|---|---|
| Balance in State Treasury from 1908 | $244 98 | |
| Appropriation for fiscal year 1909* | 600 00 | |
| Total | | $844 98 |
| Cost of Proceedings for 1908 | $438 74 | |
| Cost of reprints for 1908 | 85 68 | |
| Total | | 524 42 |
| Balance available for fiscal year 1910 | | $320 56 |
| Appropriation for fiscal year 1910 | | 1,200 00 |
| Total available for printing the Proceedings of 1909 | | $1,520 56 |

I wish to call the attention of the members of the Academy to one or two matters. First in regard to the editorial statement on the program. We desire that papers be in the hands of the editor or secretary as early as possible, in order that the Proceedings may be gotten out more promptly than last year. Reprints will be furnished of all papers printed, excepting abstracts, and these may be furnished, if request is made. These reprints are paid for by the State Printing Board.

I desire to ask for suggestions as to changing the style of binding and improving the quality of the paper for the coming year.

I would also ask that each one sending a paper for publication should give his address on the paper, so proof can be sent and the reprints mailed. This is a very important thing and I hope it will not be overlooked.

DR. FOLEY: Does anyone have any suggestions to make?

MR. J. S. WRIGHT: I am sorry to occupy so much time on the floor this morning, but I feel there is one thing that should be recognized, and that is the fact of the service rendered the Indiana Academy of Science by the past President, Mr. Glenn Culbertson, who succeeded in doubling the amount of money available for publishing. We now have $1,200 per

* The fiscal year 1909 began Oct. 1, 1908, and closed Sept. 30, 1909.

year, as against $600 before Mr. Culbertson took this in hand. I think this Academy owes him a debt of gratitude. (Applause.)

DR. FOLEY: I wish to second what Mr. Wright has said. I also wish to point out another fact, that formerly any money left reverted to the State, while now it can be carried over until the next year.

Are there any other suggestions?

MR. M. B. THOMAS: It seems to me it would be best to improve the quality of the paper and printing, and possibly of the illustrations, but that this matter should be left to the Committee on Printing, of which Prof. Bruner is the chairman.

(Taken by consent.)

MR. WRIGHT: I move that the Academy extend a vote of thanks to Mr. Culbertson for his unusual service.

(Seconded and carried.)

Report of Resolutions Committee: No report at this time.

MR. G. W. BENTON: I would like to suggest that the Academy is under obligations to the press of the city for courtesies extended, in giving us column after column of space for advertising this meeting. We have been unusually privileged in this regard, and I think it is proper and courteous that we should recognize it in some definite way. Therefore I move that we extend a vote of thanks to the press of the city for courtesies extended to the Academy in announcing this Anniversary meeting.

(Seconded and carried.)

DR. STANLEY COULTER, (for the Membership Committee): It seems to me it would be remarkably pleasant if we could mark this twenty-fifth anniversary by a large increase in membership, and if you will see that applications are in the hands of the committee some time during the forenoon, we will report on them at the afternoon session, so the neophytes will have the feeling that they are full-fledged members.

After an announcement by the Treasurer in regard to payment of dues; and another by Mr. Benton regarding the banquet tickets, etc., Dr. Foley called on Mr. D. C. Brown, the State Librarian, to report in regard to the Academy and its relation to the State Library.

PROF. D. C. BROWN: I am not a member of the Academy of Science, but as State Librarian I made an agreement with the Academy of Science by which the State Librarian is to classify, catalog and shelve the docu-

ments and reports belonging to the Academy, making them subject to removal by any members of the Academy, and subject to reference by the public. I am very greatly interested in having the State Library the center for reference of the entire State on every subject, and by the agreement made with the committee of your Academy two years ago this work has been begun and is progressing fairly well.

The agreement was that the catalog department of the State Library should, as fast as possible and as fast as funds would allow, proceed with this work. Up to the present time we have classified, cataloged, and made analytical catalogs of 143 volumes of domestic reports and 96 foreign reports, making a total of 239 volumes. These have all been bound, and there are about one hundred volumes at present ready to go to the bindery, some foreign and some domestic. These volumes are systematically cataloged and at the present time I have had them all bound alike in good buckram, with a certain kind of label on the back, with "Academy of Science" at the top and the library call number at the bottom. Inside, a label showing to whom the book belongs, and that it can be borrowed only by the members, but used for reference by the general public. I am not quite sure that it is advisable to bind all these books in exactly the same way, but it makes them easily understood when on the shelves. Members can tell instantly that that book belongs to the Academy of Science. A separate card list is also made in pencil and ink, and easily accessible at any moment.

I fancy you all understand that the binding is paid for by the library, with the understanding that if the Academy ever withdraws the books it must pay that amount, so the bills for binding are kept separate, and the public has the use of the books. The Academy would also have the right to have the cards that are made showing the books properly cataloged. Whether that will ever come, I do not know.

I am struggling as best I can for a State Library and Historical Museum, in which all the valuable records and scientific reports of the State can be kept, and in making the argument for that I have said that the Academy of Science would help.

I do not know that I can make any further statement about it, only to have it known to you that the reports are cataloged now about as fast as they come in. I have one request to make—that we may have a definite and correct list of your foreign exchanges, your domestic exchanges, and

your membership. I have had considerable trouble about that, but have worked it out fairly well so far. The foreign exchanges are made through the Smithsonian Institute at Washington. The files of the reports sent to members are paid for by the Academy. The library pays for the others, and through the library they are distributed.

I am very anxious that the members come to the library, as their coming there to use these reports will make it known to the public that the reports are there and can be used.

I believe I have nothing further of interest, but I am very anxious to see you in the library. (Applause.)

Dr. Foley: I am sure I voice the sentiments of the Academy when I thank our Librarian for the efforts he has put forth in getting the Academy library in good shape, available for use.

The program calls for greetings from the various other scientific societies after the addresses of the morning. I am informed, however, that Mr. Brossmann, representing the Indiana Engineering Society, is here and cannot remain, therefore I will call upon Mr. Brossmann at the present time.

Mr. Brossmann's address will be found in full on page 44.

Dr. Foley: I might ask if there are any other representatives of societies here that cannot remain during the period. If so, we will have the greeting at this time.

There is just one other point that might be taken up at this time, and that is the question of a summer meeting. The question was mentioned at the Executive Committee meeting last evening, but was not settled. Are there any suggestions as to whether we shall or shall not have a summer meeting? I think the Program Committee would like to have an expression from the Academy. It does not wish to announce a meeting unless somebody meets. On the other hand, it does not wish to discontinue this meeting if it is the desire of any considerable number of members to continue them. What is the wish of the Academy?

If no one has any suggestions, I will call on Dr. S. E. Earp, who fears he may not be able to remain during the entire morning, to respond for the Indiana Medical Society.

Dr. Earp's remarks will be found in full on page 40.

(Mr. P. N. Evans, Vice-President, in the chair.)

Mr. Evans: We will now proceed with the regular order of business, and will hear the President's Address by Dr. A. L. Foley, of Bloomington.

Dr. Foley's address will be found on page 89.

Following the President's address:

Mr. Evans: Evidently this chair should be occupied by a physicist instead of a chemist, so I will vacate in favor of Dr. Foley. (Applause.)

Dr. Foley: It now gives me great pleasure to introduce one who needs no introduction, Dr. John M. Coulter, of Chicago University, who will speak to us on "Recent Progress in Botany." (Applause.)

Dr. Coulter's address will be found on page 101.

Following Dr. Coulter's address:

Dr. Foley: You will note from the program that Dr. Harvey Wiley was to have been here this morning to address us. I understand Dr. Barnard has a letter from Dr. Wiley. We would be glad to hear from Dr. Barnard.

Dr. H. E. Barnard: Mr. President, I just this morning received a communication from Dr. Wiley, in which he said he was engaged in the preparation of a very important case involving one of the basic principles of the Pure Food Law. He said if he came on here for four days, he did not know what would happen to the case, and that while he would be with us in spirit and thought, it would be impossible for him to leave his work in Washington to attend this convention. He sends to you his best wishes and hopes for a successful meeting.

Dr. Foley: You will note from the program that we now have greetings from several associations, scientific and otherwise, who have sent delegates to this association at this time. I will call first for the Indiana Teachers' Association, through its President, Mr. Geo. W. Benton.

(See page 39.)

Dr. Foley: We will now hear from the Indiana Branch of the American Chemical Society, through Mr. R. B. Moore.

(See page 42.)

Following the various society greetings the Academy adjourned until 2:00 p. m.

*Saturday Morning, November 27, 1909.*

Meeting called to order by President Foley.

(After asking the members who had not already done so to leave their names at the desk, so that a complete list of those in attendance at this meeting might be obtained, Dr. Foley called for the report of the Committee on Resolutions, Mr. C. L. Mees, chairman.)

For this report see page 24.

(Moved and carried that the report be adopted.)

DR. FOLEY: It seems to me that the Academy is under great obligations to the Program Committee, especially to Mr. Butler, and I think a vote of thanks to this committee would be in order.

(Moved and carried that a vote of thanks be extended to the Program Committee, especially Mr. Butler, for the great amount of work that has been put on the program.)

REPORT OF NOMINATING COMMITTEE.

President, P. N. Evans, Lafayette.

Vice-President, Chas. R. Dryer, Terre Haute.

Secretary, George W. Benton, Indianapolis.

Assistant Secretary, A. J. Bigney, Moores Hill.

Treasurer, W. J. Moenkhaus, Bloomington.

Editor, H. L. Bruner, Indianapolis.

(Moved and carried that the report be accepted and that the Secretary cast the ballot of the Academy for these officers.)

REPORT OF AUDITING COMMITTEE.

We have gone over the vouchers of the Treasurer, the Program Committee, and the Editor's Report, and find the sums have been done correctly.

W. J. MOENKHAUS, Chairman.

(Moved and carried that the report be adopted.)

REPORT OF COMMITTEE ON MEMBERSHIP.

Thirty-five additional names reported.

Applicants for Membership elected by vote of Academy, 1909.

Thomas Billings .................... West Lafayette.
Earl Grimes ........................ Russellville.

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|---|---|
| Earl Rouse Glenn .................. | Brookville. |
| A. A. Bourke ....................... | Edinburg. |
| Geo. Hall Ashley ................... | Indianapolis. |
| James Persons Dimonds............. | Washington, D. C. |
| Guido Bell ......................... | Indianapolis. |
| Florence Anna Gates ................ | Wabash. |
| Oscar William Silvey ............... | Bloomington. |
| James E. Weyant .................... | Indianapolis. |
| John W. Woodhams ................... | Indianapolis. |
| Melvin Knolen Davis ................ | Terre Haute. |
| E. Kate Carman ..................... | Indianapolis. |
| Paul Anderson ...................... | Crawfordsville. |
| Howard J. Banker ................... | Greencastle. |
| Charles Alexander Vallam ........... | Indianapolis. |
| Thad. S. McCulloch ................. | Crawfordsville. |
| Frank Karlston Mowrer .............. | Marion. |
| E. M. Deem ......................... | Frankfort. |
| Milo H. Stuart ..................... | Indianapolis. |
| Charles Ruby Moore ................. | West Lafayette. |
| L. R. Hesler ....................... | Crawfordsville. |
| Martha Hunt ........................ | Indianapolis. |
| Brenton L. Steele .................. | Bloomington. |
| Alfred Theodore Wianco ............. | Lafayette. |
| Walter W. Hart ..................... | Indianapolis. |
| Ira C. Trueblood, Miss.............. | Greencastle. |
| Luther Cornelius Weeks ............. | West Lafayette. |
| Fermen L. Pickett .................. | Bloomington. |
| William Logan Woodburn ............. | Bloomington. |
| Roscoe Raymond Hyde ................ | Terre Haute. |
| Chas. M. Cunningham, Dr............. | Indianapolis. |
| Mason L. Weems ..................... | Valparaiso. |
| Edward N. Canis .................... | Indianapolis. |
| G. A. Osner ........................ | Crawfordsville. |
| Frederick W. Gottlieb .............. | Morristown. |
| Geo. T. Moore ...................... | St. Louis. |
| Samuel E. Earp ..................... | Indianapolis. |
| J. H. Clark ........................ | |
| Leslie C. Nanney ................... | Bedford. |
| Everett W. Owen .................... | Indianapolis. |
| Geo. Spitzer ....................... | West Lafayette. |
| Geo. N. Hoffer ..................... | West Lafayette. |
| Julius Wm. Sturmer ................. | West Lafayette. |
| Virges Wheeler ..................... | Montmorenci. |
| Harry F. Dietz ..................... | Indianapolis. |
| Chas. Brossman ..................... | Indianapolis. |

A. D. Thornburn .................... Indianapolis.
Chas. Stiltz, M.D .................. South Bend.
Jacob P. Young ..................... Huntington.
J. M. Van Hook ..................... Bloomington.
Walter M. Baker .................... Red Key.
Wm. Reynolds Butler ................ Indianapolis.
W. H. Rankin ....................... Ithaca, New York.
Omer C. Boyer ...................... Lebanon.
W. M. Blanchard .................... Greencastle.

(Moved and carried that the Secretary cast the ballot of the Academy for these names, and that the persons be considered members after paying fees and signing the Constitution.)

DR. FOLEY: I should like to bring up a matter at this time which was brought up yesterday, but we could not get an expression from the Academy. That is, in regard to the Summer meetings. Does this Academy want a Summer meeting? I think the Program Committee would like to have an expression from the members.

DR. STANLEY COULTER: I want to say that in twenty-five years' membership I have found that the Summer meeting is equivalent to about three Winter meetings in the way of uplift and encouragement. Of course, one of the objections is that a good many members—mathematicians, chemists and physicists—would not be specially interested in these Summer meetings. I would very much regret to see the Summer meeting abolished. If, however, it does not seem feasible, I presume it might be dropped. I move that the Program Committee be instructed to proceed with plans for the Summer meeting, and if in their judgment the signs are not favorable for a session, they be authorized to drop it.

W. A. McBETH: I want to second that motion. I remember with great pleasure the Spring meetings. I made it a point to attend them regularly, and through the fact that we had Spring meetings I have visited some very interesting points in Indiana which are hard to get to unless you particularly go there. The town of New Harmony was one of these places; it is full of historical associations. We went to Madison, to Bloomington, to many of the caves, and to various other points throughout the State where we would probably not have gone if it had not been for this particular attraction. Now, my own way of thinking is that if we would resolve to go to these Spring meetings they would be worth two of the Winter meetings to those who go. I am heartily in favor of resuming the Spring meetings.

(At the suggestion of Mr. Butler a standing vote was taken, which resulted unanimously in favor of resuming the Spring meetings.)

MR. BUTLER: Mr. Chairman. We have a telegram of greeting from the Ohio Academy of Science, and I move that the Secretary be instructed to telegraph the greetings of the Indiana Academy in return.

(Taken by consent.)

MR. BUTLER: In reference to the letter from Dr. Harvey Wiley read at the banquet last night, I move that a committee, consisting of Stanley Coulter, Harvey W. Wiley and C. H. Eigenmann be appointed to see that the suggestions in Dr. Wiley's letter in regard to obtaining some one to prepare a history of early science in Indiana, are carried out.

(Seconded.)

J. H. RANSOM: I would like to amend that by adding Mr. A. W. Butler's name to that committee as a fourth member.

(Seconded.)

STANLEY COULTER: I suggest that Mr. Butler be the first member instead of the fourth.

MR. BUTLER: I think the purpose of the committee is simply to study the situation, and a smaller committee is better than a large one. The three first chosen are the proper members and would be able to do the work better than a larger committee.

(Amendment put and carried; motion as amended carried.)

MR. BUTLER: I move that the Treasurer and Secretary be directed to notify all delinquent members that the constitutional rules against such will be enforced, by order of the Academy.

(Seconded and carried.)

MR. BUTLER: Another matter I think should be acted upon by the Academy. The Editor this year has not put in any bill for expenses, and the expense of editing the Proceedings will probably be larger next year, I move that an appropriation of $25 be allowed the Editor for the expenses of this year and the year coming.

(Seconded and carried.)

MR. J. S. WRIGHT: In view of the fact that the Academy has received many favors from the Claypool Hotel in giving us this room without charge, and a room for the section meetings, and other courtesies, I move

that we extend a vote of thanks to the management of the Claypool Hotel for courtesies shown the Academy.

(Seconded and carried.)

DR. FOLEY: We will now take up the program of the morning. The first number is an address by Dr. B. W. Evermann, of the U. S. Bureau of Fisheries, on "Federal Control of International and Interstate Waters."

For Dr. Evermann's address see page 119.

DR. FOLEY: The next paper is by Prof. Charles W. Greene, of the University of Missouri, on "The Speed of Migration of Salmon in the Columbia River."

An abstract of Professor Greene's address is given on page 125.

DR. FOLEY: The last paper on the program, "Some Hoosier and Academy Experiences," is by C. A. Waldo, of the Washington University, St. Louis, but Mr. Waldo is not here. The first paper, "Methods and Materials Used in Soil Testing," is by H. A. Huston, of Chicago. Mr. Huston is not here, but his paper is, and it will take about fifteen minutes to read it. It is contrary to precedent that a paper should be read by anyone but the author. However, the Academy can change that, of course, at will. What shall we do with this paper?

(Moved and carried that the paper be read.)

For Professor Huston's address see page 111.

DR. FOLEY: I am sure the members of the Academy would like to hear from anyone who has any suggestions to offer. This completes the list on the program, but we will be glad to hear from anyone else.

If you will pardon me, I would like to make a suggestion or two, one of which was made to me last evening.

Those of us who are members of the American Association know that when we register there, a number is given us corresponding to the name, address and business of the member. So all we need to do to find any man's pedigree is to refer to the number in the list, which is the registration list. Now, it seems to me that some scheme like that might be an advantage in connection with this Academy, so that any member can find out who the other man is. I know I am introduced to people a half-dozen at a time, whom I cannot place and name a few minutes afterwards. A great many people I find are like to me in that respect. We cannot associate names and faces after having been introduced to three or four persons at once. Perhaps some sort of a scheme might be adopted to advantage.

Another thing is that this meeting is the largest that we have ever had during my connection with the Academy, and the reason is evident. We have had men of national reputation to address us. I do not think this large attendance comes from the fact that this is an anniversary meeting, but from the fact that the program has been made worth while by having men who will draw people to the meeting.

You will note that the State is now doing our printing; we do not have to pay that ourselves, and you will note from the Treasurer's report that we have some money and that we are going to get more money, and we have nothing particular to do with this. Now, it seems to me that the Program Committee might arrange to bring one or two speakers here each year, speakers of national reputation, and spend some of this money for their expenses. If we could have some such program as we have had this year every year, with men like Dr. Jordan, and Dr. Coulter and Dr. Wiley, there is no question but what we would have a large attendance, and I think our funds will justify that. I merely offer these as suggestions.

H. L. Bruner: As editor of the Proceedings I would urge the importance of getting the manuscripts in as soon as possible. The fact that the Proceedings were late this year is due largely to the tardy reception of the papers by the editor. If the members will turn over their papers promptly, I will see that they get into the hands of the printer as early as possible.

Dr. Foley: I want to second what Mr. Bruner has said. I was Editor one year.

This completes the program, unless the Academy wishes to take up some of the papers which are departmental. What is your will?

(Motion to adjourn.)

[PRESIDENT'S ADDRESS.]

# Recent Developments in Physical Science.

[Publication No. 34.]

By Arthur L. Foley.

On this—the twenty-fifth—birthday of the Indiana Academy of Science, it is meet that we survey the progress made and take an inventory of stock on hand. Where were we? Where are we?

Comparing physical science of today with physical science of twenty-five years ago, I am forced to the conclusion that there has been a revolution.

In the first place there has been a revolution in the methods of teaching science. I would remind you that the physics laboratory of the University of Berlin was founded in 1863, the Cavendish laboratory of Cambridge in 1874. In 1871 Professor Trowbridge, of Harvard, was obliged to borrow some electrical measuring instruments, as the university had none of its own. It is not surprising, then, that a few years later—at the time the Indiana Academy of Science was founded—there were in the United States very few physics laboratories worthy of the name. Physics teaching in college and high school was chiefly from the text-book. Today a college which would offer work in physics without a laboratory would be considered a joke; and in order to be commissioned, a high school must have a certain minimum of laboratory equipment and the physics teacher must devote a part of his time to laboratory instruction.

In the second place there has been a complete change in the attitude of men of affairs toward the physics professor and his students. No longer do they consider us theoretical, and therefore impractical. No longer do they look with distrust or contempt on laboratory methods and data. No longer do they hold that apprenticeship and experience are sufficient for their needs. Today the large industrial concerns are establishing laboratories of their own and employing in them the best trained men they can command.

In the third place, there has been a revolution in some of our physical theories. By the term revolution I do not mean a destructive upheaval

in which the work of the past has been repudiated and destroyed and a new order of things established. I mean that some of our ideas have undergone such a complete and rapid change that what some might term an evolution is really a revolution. Indeed, we have had two revolutionary periods within the life of this Academy.

The first came in 1887 with the epoch-making researches of Heinrich Hertz. Faraday had given us his theory of lines of force and the mathematicians had attacked it. Young and Fresnel had given us the undulatory theory of light and Laplace and Poisson had "befuddled us with their objections." Ampere had given a theory of magnetism, but Poisson and Weber had given two others. To explain an electric charge we could resort to the one-fluid theory, the two-fluid theory, the potential theory, the energy theory, the ether-strain theory. Maxwell had written a treatise on electricity which few could read and no one could fully understand. A distinguished French physicist said he understood everything in Maxwell's book except what was meant by a body charged with electricity. Maxwell had given us but a vague idea of electric displacements and displacement currents, because his ideas were bound up in equations without experimental verification, or even illustration.

Then came Hertz's researches, which confirmed the fundamental hypotheses of the Faraday-Maxwell theory and "annexed to the domain of electricity the territory of light and radiant heat." [1]"Many thinkers," said Lord Kelvin, "have helped to build up the nineteenth century school of *plenum*, one ether for light, heat, electricity and magnetism; and Hertz's electrical papers, given to the world in the last decade of the century, will be a permanent monument of the splendid consummation now realized." Some one has said that Hertz enthroned Maxwell in every chair of physics in Europe and America.

It appears that many of the ancient philosophers had a shadowy idea of a medium in space which they personified and called "Aether." According to Heriod, Aether was the son of Erebus and Night and the brother of Day. The Orphic hymns speak of Aether as the soul of the world, the animator of all things, the principle of life. The children of Aether and Day were the objects about us, the heavens with all their stars, the land, the sea. Aether was the lightest and most active form of matter and Day had the power of converting it into heavier matter. Plato speaks of the

[1] Kelvin. Introduction to Jones' translation of Hertz's "Electric Waves." Macmillan, 1893.

Aether as being a form of matter far purer and lighter than air, so light that its weight cannot be ascertained because distributed through infinite space.

During the fifteen years following the publication of Hertz's researches it is probable that greater homage was paid to Ether by modern physicists than was ever given it by the ancients. The ether was appealed to from every quarter. Light, radiant heat and electric waves were ether waves. An electric charge was an ether strain. An electric current was a phenomenon in the ether and not in the wire in which it appeared to flow. Magnetism and gravitation were phenomena of the ether. Matter itself became an aggregation of ether vortices. Ether and motion were expected to explain everything. Such terms as natural philosophy and physics were discarded by some of our text-book writers who adopted such titles as "Matter, Ether and Motion"; "Ether Physics"; "Ether Dynamics"; "The Mechanics of the Ether." Physics was defined as the science of motion.

The classical mechanics of LaGrange was built on what were considered fundamental concepts—mass, force, space and time. Hertz, in his treatise on mechanics published in 1894, endeavored to eliminate force and potential energy and reduce a universe to ether movement. Space and time were not fundamental ideas, but as Kant had said, were subjective notions. We measure time by a change of space relation; that is, a movement of a star, of the earth, of a clock hand. "In a world void of all kind of movement there would not be seen the slightest sequence in the internal state of substances. Hence the abolition of the relation of substances to one another carries with it the annihilation of sequence and of time." Thus everything was made to depend upon movement. The equations of motion became the chief instruments of physical research, and the criterion by which the results of experiments were interpreted. Galileo lost his professorship because he dared to dispute the authority of Aristotle. Daguerre was for a time placed in an asylum because he said he could take a picture on a tin plate. Galvani was ridiculed by his friends and dubbed "the frog's dancing master." Franklin's paper on lightning conductors was considered foolish, and refused publication by the Royal Society. Fifteen years ago it would have been almost as disastrous for a physicist to question the authority of LaGrange or Maxwell. Not only were the *results* of experiments subjected to mathematical analysis, the *direction* of scientific investigation was largely so determined. The

question was first put to mechanics. If a positive answer was indicated the question was put to nature and the research went on. If the equations indicated a negative result the question was dropped and the research abandoned.

Physics was an *exact* science. Other sciences were not exact sciences because their theories and hypotheses could not be mathematically expressed—the relation between cause and effect was not expressible in algebraical symbols. Physics was an exact science whose fundamental principles had been discovered and its laws expressed by equations. All that remained to be done was to make more accurate measurements of physical quantities for use as coefficients and exponents.

Let me quote from the 1894 catalogue and later catalogues of one of the largest universities in the United States.

"While it is never safe to affirm that the future of physical science has no marvels in store. * * * it seems probable that most of the grand underlying principles have been firmly established and that further advances are to be sought chiefly in the rigorous application of these principles to all the phenomena which come under our notice. * * * An eminent scientist has remarked that the future truths of physical science are to be looked for in the sixth place of decimals." The foregoing is a verbatim quotation from the introductory statement preceding the list of courses in physics offered at one of our great universities, written, I think, in 1894. "Underlying principles firmly established," "Future truths in sixth decimal place," 1894. Then came the discovery of Roentgen rays, 1895; Becquerel rays, 1896; Zeeman effect, 1896; radium, 1898; atomic disintegration, the transformation of matter, the thermal effect of radioactivity, and intra atomic energy, 1903. I am unable to locate the sixth decimal idea in recent catalogues.

J. J. Thomson likens the discovery of Roentgen rays to the discovery of gold in a sparsely populated country. Workers come in large numbers to seek the gold, many of them finding that "the country has other products, other charms, perhaps even more valuable than the gold itself."

The chief value of Roentgen's discovery was not that it furnished us a new kind of light for the investigation of dark places, but in the fact that it led a host of workers to study vacuum tube discharges—the discharge of electricity in gases and the effects of such discharges on matter itself. The old dusty Crookes' tube was taken down from the far corner

of the upper shelf and regarded with new interest. In a day it had ceased to be a forgotten, though curious, plaything, and had become a powerful instrument of research. It was before Roentgen's discovery that a well-known professor said to me that he considered it foolish for one to spend any part of his departmental appropriation for a vacuum; that when he paid out money he wanted something in return—not an empty space. And yet this man was familiar with the work of Faraday and of Crookes, both of whom with prophetic mind had foreseen and foretold. Let me quote from a lecture by Faraday on the significant subject "Radiant Matter."

[1] "I may now notice a peculiar progression in physical properties (of matter) accompanying changes of form, and which is perhaps sufficient to induce, in the inventive and sanguine philosopher, a considerable degree of belief in the association of the radiant form with the others in the set of changes I have mentioned.

"As we ascend from the solid to the fluid and gaseous states, physical properties diminish in number and variety, each state losing some of those which belong to the preceding state. * * * The varieties of density, hardness, opacity, color, elasticity and form, which render the number of solids and fluids almost infinite, are now supplied by a few slight variations in weight and some unimportant shades of color.

"To those, therefore, who admit the radiant form of matter, no difficulty exists in the simplicity of the properties it possesses * * * . They point out the greater exertions which nature makes at each step of the change and think that, consistently, it ought to be greatest in the passage from the gaseous to the radiant form." The lecture from which the foregoing is a quotation was delivered in 1816, when Faraday was but twenty-four years old.

Let me quote again, this time from a lecture by Sir William Crookes delivered sixty years later, more than thirty years ago, on the same subject—"Radiant Matter."

"In studying this fourth state of matter we seem at length to have within our grasp and obedient to our control the little indivisible particles which with good warrant are supposed to constitute the physical basis of the universe. We have seen that in some of its properties radiant matter is as material as this table, whilst in other properties it almost assumes the character of radiant energy. We have actually touched the borderland where matter and force seem to merge into one another, the shadowy realm

[1]Life and Letters of Faraday, Vol. 1, p. 308.

between known and unknown, which for me has always had peculiar temptations. I venture to think that the greatest scientific problems of the future will find their solution in this borderland, and even beyond; here, it seems to me, lie ultimate realities, subtle, far-reaching, wonderful."

The developments of the last few years have demonstrated that no truer prophecy was ever uttered, and the prophet Crookes has lived to witness and to take a part in its fulfillment.

The importance of the present rejuvenation of physical science does not consist alone in the abundance of the harvest. There have been abundant harvests in the past. Consider the decade which closed one hundred years ago. In 1798 Rumford boiled water by friction. In 1799 Davy melted ice by friction in a vacuum and Laplace published his work on mechanics. In 1800 Volta constructed the Voltaic pile, Nicholson and Carlisle decomposed water, Davy discovered the properties of laughing gas, and Herschel discovered dark heat rays. In 1801 Piazzi discovered the first asteroid, Ritter the chemical rays, and Young the interference of light. In 1802 Wedgewood and Davy made sun pictures by the action of light on silver chloride, and Wollaston discovered dark lines in the sun's spectrum. In 1808 Malus discovered polarization by reflection, Gay Lussac the combination of gases by multiple volumes, and Dalton the law of multiple proportions.

So great was the exhilaration and satisfaction produced by these discoveries that many scientists of that period appear to have become infected with something akin to the "sixth decimal" delusion. "Electricity," wrote the French scientist Haüy, "enriched by the labor of so many distinguished physicists, seems to have reached the term when a science has no more important steps before it, and only leaves to those who cultivate it the hope of confirming the discoveries of their predecessors and of casting a brighter light on the truths revealed." A statement which was almost immediately followed by the discoveries of Oersted, Ampere, Seebeck and Faraday. A statement which has been followed by the telegraph, the telephone, the dynamo, the motor, the electric light, the electric railway, the Roentgen rays, and the wireless telegraph and telephone.

If anyone today is disposed to criticise the men of science of other times because of their limited view, their complacent opinions and their intolerance of all that did not agree with theories they considered established, let him first read and ponder over what One spake about motes and beams.

The real significance of recent developments is in the fact that they change—in a way revolutionize—some of our ideas of things. And here let me say that proven facts and proposed theories should not be confused. A theory is simply a working hypothesis, invented for the purpose of explaining facts, to be discarded when facts are discovered with which the theory is not in harmony. A theory may explain many facts, it may be generally accepted, it may have survived for generations and be false. The phlogiston theory, the corpuscular theory are two examples. Shall we say that the theory of the indestructibility of matter and of the conservation of energy are two others?

The usual chemistry text-book would have us believe in the indestructibility of matter because the chemist can change the form of matter almost at will, and in all the chemical reactions there is no loss of weight. In replying to this argument I wish to make three points.

First. The balance, notwithstanding the statement of text-books, compares weights and not masses, and it is only because weight is assumed to be proportional to mass that we say we determine mass by the balance. What we really compare is the gravitational force which the earth exerts on two masses, and we have no a priori right to assume that this gravitational force is absolutely independent of the state or molecular arrangement of the attracted body. Why, for instance should we expect an absolutely uniform field of force about a crystal when that same crystal will, if placed in a proper solution, continue to grow symmetrically, and perhaps replace a broken-off corner before beginning its growth?

It is conceivable that there should be a loss of weight in chemical reactions and yet no destruction of matter. It is possible that mass and weight are not strictly proportional. If J. J. Thomson were not disposed to question the equation $w = m \, . \, g$ he would not have experimented with a pendulum of radium, and he would not now be experimenting with a pendulum of uranium oxide.

In the second place there *is* an apparent change of weight in chemical reactions as has been shown by several experimenters, notably by Landolt,[1] who found a loss in forty-two out of fifty-four cases. The chemical reactions were brought about in sealed glass tubes which generally weighed less after the reactions than they weighed before. Later[2] it was found that some of these losses might be attributed to temperature and volume

[1] H. Landolt. Preuss. Akad. Wiss. Berlin, Sitz. Ber. 8, pp. 266-298, 1906.
[2] Landolt. Preuss. Akad. Wiss. Berlin, Sitz. Ber. 96, pp. 354-387, 1908,

changes. Whatever the testimony of the balance may have been, some of the reactions must have been accompanied by a loss of weight, for it has been proven by chemical means that such reactions are frequently attended by the escape of something through the walls of the glass tubes.[1] This loss is readily explained by the disintegration theory. If one wishes to explain it by assuming the diffusion of ordinary gases through the glass walls of the tube he must explain the fact that, in many cases, it was the heavy and least volatile substances that escaped fastest.

In the third place the element of time has been overlooked. Matter may be disintegrating, but at such a slow rate that in the limited time over which experiments have been extended the balance has failed to detect the change. As far as our experience goes the time of rotation of the earth is constant; but we know that it cannot be absolutely constant. The moon has slowed down until it takes a month to make one turn. To an ephemeral insect almost everything would appear to be eternal. With due respect for the balance and the wonderful work it has enabled chemists to do, it must be admitted that it is, comparatively, a very crude instrument. Let me prove it.

Suppose we fix the limit of sensibility of the balance at one one-thousandth of a milligram. Our books on chemistry tell us that 1 c c of gas, say hydrogen, at ordinary pressure contains $4 \times 10^{19}$ molecules. The density of H being $896 \times 10^{-7}$, then 1 gm. of H would consist of $(4 \times 10^{19}) \div (896 \times 10^{-7})$ molecules. Taking 112 as the ratio of the molecular weights of radium and H, then 1 gm. of radium would consist of $[(4 \times 10^{19}) \div (896 \times 10^{-7})] \div 112 = 4 \times 10^{22}$ molecules. Therefore .001 mgm. of radium would consist of $4 \times 10^{16}$ molecules, and this would be the smallest possible number that our most sensitive balance could detect. If the gram of radium were disintegrating and its molecules escaping at the rate of a million per second it would require $4 \times 10^{10}$ seconds $=$ 463,000 days $=$1270 years for that gram of radium to lose in weight only the one-thousandth part of one milligram, all the while its molecules trooping away at the rate of a million per second.

The population of the earth is about 1,500 millions. The smallest number of molecules a balance will detect is $4 \times 10^{16}$, or about 26,600,000 times the population of the earth. We wonder if Mars is inhabited. If a Martian were to come to the earth to make an experiment to determine whether or not the earth is populated and he had no better instrument

[1] C. Zenghelis. Zeitschr. Phys. Chem. 65, 3, pp. 341-3?8, Jan. 5, 1909.

"for the detection of the existence of a man" than is the balance for a molecule, he would be obliged to go back and report the earth uninhabited. In fact his instrument for the man test would need to be 26,600,000 times as sensitive as the balance to give him even a hint of the probability of an earth population.

Thomson says that the smallest quantity of unelectrified matter ever detected is probably neon, and this was discovered by the spectroscope—not the balance. But the number of molecules of neon required to give a spectroscopic effect is about ten million million, or about 7,000 times the population of the earth. It has been shown that the presence of a single charged atom can be detected by electrical means. Thus the electroscope is millions of millions of times as sensitive as the spectroscope, which is itself in many cases far more sensitive than the balance. This explains, in part, why radium was discovered by physicists, and why physicists have been most active in all the work which has had to do with the theories of electricity and matter. If chemists wish to compete with physicists in this field of investigation they must adopt physical methods and apparatus or devise some of their own which shall be far more sensitive than the balance or spectroscope. Further, many of the great chemists of the world need to awake to the fact that there is something doing and that they are not doing it. Their indifference is surprising. Only three months ago one of them expressed the following sentiments in a paper read before the chemical section of the British Association. [1]* * * "Those who feel that the electron is possibly" (note the possibly) "but a figment of the imagination will remain satisfied with a symbolic system which has served us so long and so well as a means of giving expression to facts which we do not pretend to explain. * * * Until the credentials of the electron are placed on a higher plane of practical politics, until they are placed on a practical plane, we may well rest content with our present condition and admit frankly that our knowledge is insufficient to enable us even to venture on an explanation of valency." Think of it! We, the chemists, "remain content" in this day when, as the Hon. A. J. Balfour has said, the attempt to unify physical science and nature [2]"excites feelings of the most acute intellectual gratification. The satisfaction it gives is almost

[1]Scientific American Supplement. 63, No. 1761. P. 219, Oct. 2, 1909.

[2]"Reflections Suggested by the New Theory of Matter." Presidential Address, British Association for the advancement of Science, 1904. Science. 20 No. 504, pp. 257-266, Aug. 26, 1904.

aesthetic in its intensity and quality. We feel the same sort of pleasurable shock as when from the crest of some melancholy pass we first see far below the sudden glory of plain, river and mountain." "Rest content!" No wonder the Noebel prize in chemistry was awarded to Rutherford, a physicist.

As to the second principle, the conservation of energy, some have had misgivings. It was Kelvin, I believe, who said that radium placed the first question mark after this great principle. Many have refused to believe in the electron and disintegration theories because they saw, or thought they saw, in these theories a contradiction of the principle of energy conservation. Personally I do not see that there are necessarily any contradictions. But even if there were and we were therefore justified in rejecting the theories proposed to explain the facts, we certainly should not be justified in rejecting the facts themselves.

In this connection I am reminded of the story of a lawyer whose client was placed in jail for some very trivial offense. When the lawyer learned the nature of the charge he said to his client: "My friend, they cannot put you in jail on such a charge as that." "Yes, but they have," replied the prisoner. When our physicist says that radium cannot remain at a higher temperature than its surroundings and continue to radiate heat, as that would be contrary to the second law of thermodynamics, the answer is, Yes, but it does. When he says that it cannot continue to radiate energy without receiving energy from some other body, as that would be contrary to the principle of the conservation of energy, the answer is, Yes, but it does it.

When some one says that helium or carbon dioxide cannot appear in sealed tubes which contained no trace of these substances to begin with, the answer is, Yes, but they do.

Let us suppose that we have a mass of gunpowder and that it is possible to, and we do, cause it to explode, one grain at a time, each grain firing its neighbor as in the fuse of a firecracker. The temperature of the mass of gunpowder will be higher than its surroundings, and it will give off heat and other forms of energy and continue to do so as long as the powder lasts. No one would think of calling this an exception to the law of the conservation of energy or the second law of thermodynamics. The source of the energy is the atomic potential energy of the powder itself.

Let us suppose that we have a sphere with frictionless surface rotating at an enormous speed. Suppose that particles of matter are thrown

off at frequent intervals. These particles, on account of their high speed, have considerable potential energy. Thus the sphere continues to give off energy without receiving any as long as any mass remains. The source of the energy is the kinetic energy stored in the sphere at the outset, of which energy we are conscious only when we have some method of detecting and slowing down the projected particles.

Thus the energy radiated by radium might be stored within the radium atom as potential energy and liberated by a sort of atomic—or sub-atomic—explosion. Or it might be stored as kinetic energy—of revolving electrons—and liberated gradually as these electrons escape from their orbits. It might be stored in both forms. In any case it is intra-atomic energy because stored *within* the atom itself and liberated only by atomic change—disintegration. In neither case would there be a violation of the principle of the conservation of energy or of the second law of thermodynamics. Sooner or later all the energy will have been radiated. The fact that the supply is destined to last so long is what appeals to us as wonderful. And so it is. The world is full of wonderful things to anyone who pauses long enough to think.

In this paper I have endeavored to give a general notion of the trend of thought and investigation in physical science rather than an enumeration and discussion of discoveries and theories. I might say, however, that there are strong reasons for believing in the molecular structure of electricity the electrical nature of matter, and the dependence of mass upon velocity. The theories of radioactivity and disintegration of matter are fairly well established. According to Ramsay, one of the most eminent chemists in the world, "we are on the brink of discovering the synthesis of atoms, which may lead to the discovery of the ordinary elements." Perhaps the dream of the alchemist is about to be realized. Certain it is that we are face to face with energies of which no one even dreamed a few years ago. Whether we call this energy intra-atomic, sub-atomic, interelemental or some other name, we know certainly that it exists, and that it exists in quantities far beyond the power of man's mind to comprehend. Man hopes some day, somewhere, somehow, to discover the means of unlocking this infinite storehouse. If this discovery is ever made, all the others which man has ever made will pale into insignificance beside it.

Lodge says of the one-pound shot and the one-hundred-pound shot which Galileo dropped from the top of the Leaning Tower, that "their

simultaneous clang as they struck the ground together sounded the death knell of the old system of philosophy and heralded the birth of the new." The age of reverence for authority had passed away and the day of experimental investigation had dawned.

In a sense the discoveries of the past few years have resulted in a similar revolution. The revival of the experimental method has been complete. Accepted theories are being put to the test. What we have long regarded as proven facts are being questioned and, in many cases, challenged. There is no field of investigation which has not been cultivated anew.

In closing I wish to quote from the presidential address of J. J. Thomson[1] before the British Association at its last meeting. "The new discoveries made in physics the last few years, and the ideas and potentialities suggested by them, have had an effect upon the workers in that subject akin to that produced in literature by the Renaissance. Enthusiasm has been quickened and there is a hopeful, youthful, perhaps exuberant, spirit abroad which leads men to make with confidence experiments which would have been thought fantastic twenty years ago. It has quite dispelled the pessimistic feeling, not uncommon at that time, that all the interesting things had been discovered, and all that was left was to alter a decimal or two in some physical constant. There never was any justification for this feeling, there never were any signs of an approach to finality in science. The sum of knowledge is, at present at any rate, a diverging, not a converging series. As we conquer peak after peak we see regions in front of us full of interest and beauty, but we do not see our goal, we do not see the horizon; in the distance tower still higher peaks, which will yield to those who ascend them still wider prospects, and deepen the feeling, whose truth is emphasized by every advance in science, that 'Great are the works of the Lord.' "

[1]Scientific Am. Sup. 63, Nos. 1757 and 1758, pp. 154, 155 and 174-176. Sept. 4 and Sept. 11, 1909.

# Recent Progress in Botany.

By John M. Coulter.

Mr. Chairman and Members of the Academy: When I face the Indiana Academy of Science at its twenty-fifth anniversary, I feel more like speaking of old times than upon any technical subject. However, perhaps some of these reminiscences may appear at the banquet tonight, and I will restrict myself just now to the program.

It is very hard for one who has not lived and worked through the period covered by the history of this Academy to appreciate the changes that have taken place in the science of botany. Those of you who have come into the subject during the last decade can hardly have a full appreciation of what you have missed and of what rapid development has taken place. At the time this Academy was being founded, almost all the instruction and investigation in botany was in taxonomy or classification, and that was chiefly restricted to the classification of flowering plants. I shall not weary you by recounting all of the important changes that have taken place since that time, but I wish to point out a few things that have impressed me.

The first impressive change is the tremendous development and differentiation of the subject during the period covered by the history of this Academy. In the background we have still the old historic field of taxonomy, which is being cultivated with greater zeal than ever. But the first change to note is the great development of the comparatively new science of morphology. In these days morphology has come to mean the structure and evolution of the plant kingdom as a whole, and its development has been little short of marvelous. Perhaps the first change from the old régime was brought about in this country by the appearance of Bessey's Botany in 1880, and from that date began the development of modern morphology in the United States.

In connection with the development of morphology there have grown up various expressions of it that have demanded special technique. The first of these to appear was that which is known as cytology. In collecting the facts in reference to the cell as a unit of structure, morphologists soon discovered that something must be known about cell structure, and

thus a very special technique has been developed and is still developing. Cytology might be defined, therefore, as morphology at the limit of technique.

In more recent years there has been another outgrowth from morphology and still a part of it. For many years there had been what was recognized to be a great rubbish heap of facts called anatomy. For example, the classic "Comparative Anatomy of Phanerogams and Ferns," by De Bary, contains a mass of facts, but they are inchoate. Many of them were used in instruction, for in the early days of morphological instruction facts were simply collected without reference to their relationships. Presently, as morphology began to develop ideas, it was felt that these anatomical facts might mean something when organized; but in the absence of such organization they were largely abandoned in instruction. Recently, however, there has been rescued from this rubbish heap the new subject of vascular anatomy, which has become a tremendous instrument in the development of our knowledge of plant groups and of the evolution of vascular plants in particular. Thus vascular anatomy has greatly extended morphology, which at first chiefly concerned itself with the reproductive structures. It still remains for some one to organize in a similar way the vegetative structures outside of the vascular system, and then morphology for the first time will have its facts fairly in hand.

Under the shadow of this morphological development there appeared another growth known as pathology. The progress made in plant pathology during the period covered by the life of this Academy is familiar to many of its members. It began as morphology, but as it progressed it became more and more clear that it would have to join itself to physiology, and so pathology may be called a cross between morphology and physiology in its recent development.

Another great field that came in connection with this development of morphology, even more recently, is paleobotany. There has been such a subject ever since people have uncovered plant remains and their impressions in the rocks; but its method was to match fossil fragments with living plants, so that identification was always uncertain. The technique of today, however, has enabled us to secure knowledge of structures, and since vascular anatomy has been put upon a phylogenetic basis we have a key by which the relationships of these ancestral plants may be unlocked.

I can only mention the remarkable advance that has taken place in plant physiology, and also in the new subject of plant ecology. There should be added plant breeding, which has not only its important scientific aspects in connection with theories of heredity and the origin of species, but has also such enormous practical applications that it is reaching out into the needs of men.

This gives merely a glimpse of how the old science of botany, as it really was when this Academy was founded, has branched out into its present field of achievement. The student of twenty-five years ago who had studied botany in our colleges and learned just enough about gross morphology to be able to use Gray's "Manual" intelligently, and who regarded that to represent all there was in botany, would be astonished to see the development of today.

Following this outline of the expansion of botany in general, I wish to speak of three or four of the most notable advances made in my own special region of morphology, and that is the morphology of vascular plants. To me the most striking feature of morphological progress during the last twenty-five years has been the breaking down of the old barrier set up between what were called cryptogams and phanerogams, the barrier that separated fern plants from seed plants. Not only was this felt to be a solid barrier, but even in universities chairs of botany have been distinguished on the basis of this division of plants. If there is any place in the whole series of plants where there is no gap between great groups it is this very place. I can call attention only to two conspicuous facts that stand out in this connection. One is the discovery a few years ago that certain gymnosperms (cycads) possess fern-like swimming sperms, a feature that associates these seed plants very closely with ferns. The second is the discovery during the present decade of the great paleozoic group of fern-like seed plants. All are familiar with the fact that the coal vegetation was thought to be largely a fern vegetation because the preserved leaves looked like fern leaves; but it is now recognized that all of these great frond groups of the coal vegetation were seed-bearing plants. In fact, paleobotanists are sure now of only one family of paleozoic ferns.

Another fact of equal interest is the uncovering of the so-called mesozoic cycads. These have proved to be far removed from the other gymnosperms in their essential characters. We have a sort of national pride in

the uncovering of this singular group, because the greatest deposits are in this country. The work of Wieland in revealing the rich deposits of these plants in the Black Hills region and in sectioning the cones with admirable skill and patience is well known. For the last five months Wieland has been exploring southern Mexico, and has discovered a section 2,000 feet in thickness that is packed with the remains of this peculiar group, making it undoubtedly the greatest deposit of these plants in the world. They are regarded now as of great interest because the peculiar structure of their cones has suggested the possibility that they may be a group of gymnosperms that has given rise to angiosperms.

Perhaps another notable change that deserves mention is the practical demonstration of the relationship between the two groups of angiosperms. It was thought once that the monocotyledons were the more primitive angiosperms, and that the dicotyledons were the more recent. We feel assured now that the monocotyledons have been derived from dicotyledons, for every monocotyledon starts with the vascular system of a dicotyledon; and if there is anything true in the old theory of recapitulation, the relationship of these two groups is evident.

Perhaps the most notable change in morphology is the change in mental attitude, and particularly in reference to the construction of phylogenies. I remember that at the early meetings of this Academy we were in the habit of constructing very complete and satisfactory phylogenies. We were sure just how one plant group descended from another. That is always easy when the facts are few; but now that facts are numerous, no one is able to construct a satisfactory phylogeny. No one imagines now that any living group has descended from any other living group.

Another marked advance is the change of mental attitude in connection with morphological work, in which morphology has clasped hands with physiology. I can only indicate some of its results. It has destroyed the old rigid categories. Botany was once largely an extensive system of terminology. Now we have passed from the days of terminology to the days of knowledge, and terminology no longer masquerades as knowledge. Not one of the old definitions has stood the test of experimental morphology. Experimental morphology has also helped to rid us of that old, Calvinistic notion of predestination in plant organs. Once it was thought that every primordium was destined to be one particular structure and nothing else. Now we know that a primordium may become almost

anything under appropriate conditions, and is not destined to be some particular structure.

One of the most interesting recent results of experimental morphology has been that obtained in experimental work on heterospory. It has been shown that it is possible to develop megaspores from cells that ordinarily develop microspores. It is such results that are playing fast and loose with our old conceptions of rigidity of structure and function.

I can merely mention the field of plant physiology. If I speak of the changes that have taken place within the last twenty-five years, I must show the atmosphere in which we are living by assuring you that I am not the one to make such a presentation. In the old days one man taught all there was of botany, and probably he taught all there was of science. Today I have been compelled to ask a competent plant physiologist concerning the notable changes. He tells me that there are two conspicuous changes in the point of view. One is the gradual passing of the old vitalistic idea, which implied that there was some such thing as vital force that explained most things. Now the facts are explained, not in terms of vital force, but in terms of chemistry and physics. Another shifting point of view is a change from the old idea that form and structure are the result of some mysterious law of development, to the idea that form and structure are entirely expressions of the conditions under which growth has been conducted.

The very new field of ecology at present is in the condition of these other fields more than a decade ago. Young fields are largely jokes to the older ones; but there has been a change in ecology during the last few years. It has passed from the stage of inchoate observation, in which instruction in ecology could not be differentiated with distinctness from a holiday excursion, to methods of precision.

In conclusion, as one looks out over this great progress, he finds that it is all really an inevitable evolution from the stimulus that was given first by Hofmeister in 1898 to morphology, and ten years later by Charles Darwin to biology in general.

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# Darwin Fifty Years After.

By Dr. David Starr Jordan.

Scientific men, as a rule, do not pay much attention to birthdays; but certain anniversaries have been impressed upon our minds of late, and in the last two years there have been many celebrations: The two hundredth anniversay of Linnaeus, and the one hundred and fiftieth of his great work, "Systema Naturæ"; the one hundredth anniversary of the birth of Agassiz, the greatest teacher of science; the one hundredth anniversay of the birthday of Charles Darwin, and the fifth anniversary of the publication of "The Origin of Species," the greatest landmark of the history of the nineteenth century. Twenty-five years ago we note another landmark of import to us. It was then that Amos Butler brought his Brookville academy to Indianapolis, where its first meeting was held on December 29, 1885. As I was just then elected president of Indiana University, the youngest of all the college presidents—and the greenest—being, therefore, by some preferred to the drier article, I was made president. With this came the suggestion that two others who, like myself, had fought each year on the bloody sands of the educational arena of Indiana—John Coulter and Harvey Wiley—would be my successors.

At that time the idea of evolution was in the air, the theory of descent, that the forms now living were created, not by mysterious power, but by the operation of natural selection and the survival of the fittest. It was my fortune to have been brought up as a student of Agassiz, having heard all his lectures on this subject, and inherited his prepossessions. It was my own studies of animals which led me little by little to become an evolutionist, and I have said that I went over to that view of the case about as graciously and as willingly as a cat which a boy draws across the carpet by its tail.

I remember it was out at Broad Ripple, just north of this city, where Copeland and myself first definitely decided that we were converts to Darwinism. The little sand darter in the river is a sort of perch, but differs from any others in having very few scales, and these very thin ones. We testified to our faith by an article in which we said that these little animals are derived from the scaly perches; that we did not know whether it has

lost its scales because it buries itself in the sand and does not need them, or whether it buries itself in the sand because it has no scales and needs protection, or whether burying itself in the sand there has come to be a gradual selection of those whose scales are fewest and thinnest. Anyhow, we were sure of its origin, and that it was descended from some of the other forms of dwarf perch to that called the Johnny Darter.

Many men before Darwin had taught the theory of descent, but Darwin gave the first rational exposition of how it came about by natural processes. He showed that adaptation is the natural result of the survival of the adapted in the struggle for existence. Variation is everywhere among animals and plants. No two animals or plants are ever alike. There is everywhere a great wealth of life—more are born than can mature, and those survive and live who are able to fit themselves into the scheme of life. Darwin did not believe in evolution in vacuo, that is, evolution wholly independent of external circumstances and conditions, but this heresy that the laws of evolution, which are simply the way things come about, can produce evolution and divergence without any except metaphysical causes, still has a large body of followers. It is, in my judgment, one of the heresies of the present time.

In the evolution of any species in the rough-and-tumble of life, we have these four elements: Variation, heredity, selection and segregation. Variation is the starter. It is interwoven with the operation of heredity. The favorable variation survives, and the animal or plant possessing it gives rise to the next generation. This is selection.

The operation of isolation is this: A group becomes separated by some barrier which the individual can not cross. Little by little the species become separated into two or more species, one just as well adapted as the other. It is not often that differences between species are differences in adaptation. It is therefore not often that they are due to natural selection. The final difference, the final polishing or rounding off of the species giving it its distinctive minor character, is due to isolation. Variation and heredity are inside the individual. The incidents of selection and isolation are of the outside world. They are part of the modifying conditions of life. Without contact with the outside influences, in my belief, there is no evolution.

Darwin may be compared to an explorer in a new country. From some high point he makes a map of the country, locating its salient fea-

tures, its rivers, lakes, peaks and cliffs. The detail must be worked out by those who come after. In the case of Darwin the map remains substantially as it was, although many have worked at the various details with which the modern chart is filling up. The discovery of the microscope has enabled us to frame a rational theory of heredity and to understand with some degree of certainty the physical basis of the functions of inheritance. The morphology of animals has been very fruitfully studied by many men. Many others have developed the history of past life on the earth, and we would have to have a theory of evolution to account for this, if Darwin had not furnished one already.

The three men most famous since Darwin are these: Wagner, Weissmann and Mendel. Mendel died before Darwin wrote and his work on the "Heredity of Peas" was forgotten until after Darwin's time, but has become a very important factor in our experimental studies of living forms in relation to inheritance. Wagner was the first one to lay adequate stress on the idea of isolation as a species-forming influence. His weakness was that he rejected selection as an element, assigning to isolation the impossible task of accounting for all the external phenomena in the origin of species. To Weismann we owe more than to any one else our present knowledge of heredity.

Theories of less importance are Eimer's orthogenesis, which has a good deal behind it, and which we shall probably accept if some genius will arise to tell us what it means. It rests on the fact that we have many long series of animals which seem to have progressively varied as time went on.

The study of the mutations of the evening primrose by De Vries has given many hints as to possibilities in plant breeding. I do not believe that the theory that species are mainly or largely formed by sudden mutations will survive the present generation of De Vries' followers, but the impulse given to experimental study of plants will long continue.

More than thirty years ago I used these words in Indianapolis:

"Darwin lies in Westminster Abbey, by the side of Isaac Newton, one of the noble men of the past whose life had made his own life possible. Of all who have written or spoken, by none has an unkind word been said. His was a gentle, patient and reverent spirit, and by his death has not only science, but our conception of Christ, been advanced and ennobled."

## Methods and Materials Used in Soil Testing.

By H. A. Huston.

The consumption of commercial plant foods in the United States has reached approximately 5,000,000 tons and the cost to the consumer is nearly equal to the sum which we formerly paid for imported sugar, and which became the slogan in the campaign to establish the beet sugar industry in America—$100,000,000.

The industry is established, but by no means stationary. It has increased at least 50 per cent. during the past five years, a very high rate considering the magnitude of the business.

In the manufacture and control of these products there is employed a large number of chemists, and the Association of Official Agricultural Chemists, now over a quarter of a century old, was originally formed for devising suitable methods of analysis for these products. Thirty-three States have special laws for fertilizer inspection. The American Chemical Society recently organized a Division of Fertilizer Chemists, and most of our agricultural colleges and experiment stations devote a considerable amount of attention to the subject.

The farmer wants to know the facts about commercial plant foods and all officialdom, from the bureau chiefs of the National Department of Agriculture to the local speaker at the township farmers' institute, undertakes to enlighten him.

In those sections of the country where fertilizers have been longest used—along the Atlantic, the eastern gulf coast and the upper Ohio Valley—the experiment stations and control officials appreciate the magnitude and importance of the industry and understand its vital relation to crop production. In marked contrast to this is the state of affairs in the greater part of the great area drained by the Mississippi, where the most of our maize, wheat and oats are produced. Here we find also the curious combination of land rapidly increasing in money value and at the same time declining in productiveness, while the cost of farm labor is increasing. These circumstances cause the farmer to inquire how his crops may be increased and whether commercial plant foods may be profitable in this connection.

Some thirty-five years ago the winter wheat growers of the Ohio Valley began to use fertilizers, most of the material being the side products of the packing houses, mainly bone meal. Very profitable results were secured and the trade rapidly increased. In time acidulated goods were introduced, often being mixtures of equal parts of acid phosphate and bone. Later came the "complete" fertilizer, being ammonia 2, available phosphoric acid 8, and potash 2 per cent. This is still the so-called basal formula, that is, the one used as a starting point in calculating the trade value of goods with different formulas. About two-thirds of the fertilizer used in that section consist of complete fertilizer; the use of bone and ammoniated phosphate is declining and the use of mixtures of acid phosphate and potash is rapidly increasing. Common applications for wheat are from one to two hundred pounds per acre, and it is almost invariably applied with a fertilizer attachment at the same time the seed is sown. The efficiency of the fertilizer in securing a stand of clover, the seed of which is sown before the wheat starts its spring growth, is a point to which the farmers attach considerable importance and the increase in clover production may in part account for the reduction in the amount of nitrogen in the fertilizers now used as compared with that used at an earlier period.

The use of fertilizers gradually extend to other crops, but fully two thirds of the fertilizer sold in the Ohio Valley are used on winter wheat. The general tendency in composition has been to reduce the nitrogen and increase the potash, while the phosphoric acid has remained practically unchanged. Ready mixed brands are the rule, home mixing the rare exception.

It is, however, unnecessary to state that much of this plant food has been used in a most haphazard way and that both buyer and local seller knew little about the composition of the goods sold or their fitness for the crop or soil on which they were to be used.

The one thing which stood out very clearly was that they paid; that by their use good crops of wheat could be secured where unprofitable crops grew before; and that a stand of clover or grass could be secured, a suitable rotation of crops established and maintained, and that the cost of the fertilizer was returned many fold in the increase of wheat grain alone. Ten pounds of fertilizer costing from ten to fifteen cents produced on the average an increase of a bushel of wheat. This condition exists over much of the winter wheat belt extending from Kansas east and com-

prising an area of probably 200,000 square miles. These facts have existed too long and cover too much territory to be ascribed to local peculiarities of soil or season. The wheat grower knows that fertilizers pay. But as brands multiplied the question arose which is the more profitable, and many made simple tests of different brands in which the popularity of the local agent received more consideration than the amount and kind of plant food in the goods; they obtained the confusing results that might have been expected under these conditions. Better informed farmers applied to their experiment stations and agricultural colleges for aid, and in most cases were surprised to be told either that commercial plant foods did not pay or that they were unnecessary.

An examination of the records of field tests conducted by experiment stations in the winter wheat section shows that many experiments have been made, especially on wheat, and that most of them have been reported unprofitable. This apparent conflict between the results of practical and scientific agriculture has to some extent prevented the extension of the sale of plant food to territory where it was very much needed. One may fairly inquire why the results of the experimental field tests differ so widely from the results obtained in ordinary farm practice in the same sections.

First, we may consider certain things that are general in their nature. Many experiments are reported where relatively heavy applications of farm yard manure have been compared with applications of various brands and quantities of fertilizers without any clear statement or apparent knowledge of the composition of the latter. Such experiments are almost invariably reported as showing that manure is more profitable than the fertilizer, which is not strange in view of the fact that in the valuations the full cost of the fertilizer is charged up, while to the manure is charged only the cost of hauling. In such reports there is often a very clear intimation that the result is quite in line with the preconceived notions of the experimenter and that in discouraging the use of "expensive fertilizers" he is at least telling farmers what they like to hear even though it conflicts with what they need to know.

The method of application of the plant food is in many cases responsible for a considerable part of the difference observed between field practice and plot experiments. Application with the drill at the time of sowing small grains, which is the common method, frequently gives profitable

results when the same amount and kind of fertilizer applied broadcast is unprofitable, and the same remark applies to light applications on maize.

One of the principal reasons for unprofitable results from plot tests is found in failure to make a distinction between the fertilization of crops producing high money values per acre, like truck and fruit, where the whole plant food supply may be profitably secured from chemical manures, and such crops as wheat, oats and maize, where the chemical fertilizers must be used to supplement and balance the supplies from the soil, farm yard and legume field. The cost of full rations of commercial nitrogen can only occasionally be recovered in the wheat crop and rarely if ever in the case of oats and maize. Double rations of phosphoric acid are often profitable and from one-half to full rations of potash. In most of the early plot experiments full rations were used, and sometimes the cost of the fertilizer for maize was greater than the total sum received for the crop even when the yields were good.

Perhaps the contrast between the plot tests and the farm practice can be shown better in the form of the amounts per acre and the formula. In some of the wheat plot tests extending over twenty years the fertilizer is the equivalent of 500 pounds per acre of goods having formula of nitrogen 10 per cent., phosphoric acid 5 per cent. and potash 6 per cent.; at the same time this series was started the common wheat fertilizer was 100 to 200 pounds per acre of 2-8-2, which has gradually changed to 2-8-6; nitrogen is sometimes increased to 3 per cent. The maize series of plots received the equivalent of 1,000 pounds per acre of a goods having a formula of nitrogen 12 per cent., phosphoric acid 4 per cent. and potash 6 per cent., while farm practice on maize uses 100 to 300 pounds per acre of goods having little or no nitrogen and containing from 5 to 10 per cent. phosphoric acid and 4 to 10 per cent. of potash. For clay soils a common maize fertilizer is 0-10-4, for loams 0-8-8 and for black sandy soils 0-6-10, while on the peat or muck soils 100 pounds per acre of muriate of potash or its equivalent in kainit are commonly used. A small amount of nitrogen is sometimes added, usually about 1 per cent.—rarely over 2.

The cost per acre of the maize fertilization would be about $30 for the plot work and from $1 to $4 per acre for the fertilizers commonly used. The cost per acre of the wheat fertilization would be about $15 for the plot work and from $1 to $3 per acre for the fertilizers commonly used.

In general it may be said that the fertilizers used on wheat and maize furnish about as much phosphoric acid as the crop removes, rarely as

much as one half ration of potash and never over one-fifth ration of nitrogen, while the plot experiments have undertaken to supply full rations for a full crop, which is fully double an average crop.

The quantities of fertilizer used in the plot tests mentioned above seem quite absurd to the American grain grower, yet they are very conservative compared with another set inaugurated at about the same time in which 2,000 pounds of acid phosphate, 600 pounds of sulphate of potash and 600 pounds of sulphate of ammonia per acre were used, or with an extensive set of orchard experiments in which the plans called for the application of 40 pounds of muriate of potash with corresponding amounts of nitrogen and phosphates to each two year old tree.

In the case of the plot experiments conducted for the purpose of determining the value of the different plant foods, the excessive quantities have often caused a profit to be shown for only the particular plant food which was most deficient, while if more reasonable quantities had been used each would have shown a profit. It is not unusual to find reports of these experiments that recommend the use of a single plant food as all that is necessary merely because it was the one that chanced to give the largest profit.

As compared with this line of plot experiments with full rations we may, perhaps, devote a moment to results of plot experiments where amounts and formulas generally used in farm practice were taken as a basis.

On a typical worn clay wheat land an experiment was undertaken on the basis of 300 pounds per acre of goods containing nitrogen 3 per cent, available phosphoric acid 10 per cent and potash 6 per cent, each element being omitted in turn in the usual way.

The following results were obtained:

| Fertilizers applied per acre. Equal to— | Yield, bushels per acre. | Reduction from Omitting | | | |
|---|---|---|---|---|---|
| | | Nitrogen. | Phos. Acid. | Potash. | All. |
| 300 lbs. 3-10-6.......... | 33.8 | ...... | ...... | .... | .... |
| 300 lbs. 0-10-6.......... | 29.1 | 4.7 | ...... | .... | .... |
| 300 lbs. 3- 0-6.......... | 7.6 | ...... | 26.2 | .... | .... |
| 300 lbs. 3-10-0.......... | 25.0 | ...... | ...... | 8.8 | .... |
| None.................... | 6.5 | ...... | ...... | .... | 27.3 |

| | |
|---|---|
| The nitrogen in the fertilizer cost per acre | $1 80 |
| The phosphoric acid cost per acre | 1 50 |
| The potash cost per acre | 1 10 |
| The complete fertilizer cost per acre | $4 40 |

The nitrogen increased the crop 4.7 bushels at a cost of $1.80, the phosphoric acid increased it 26.2 bushels at a cost of $1.50, while the potash increased it 8.8 bushels at a cost of $1.10. As wheat sold at 90 cents per bushel it will be seen at a glance that all the plant foods were used at a profit, although, of course, we are not in a position to show that the combination is the one most profitable. Nor do we know that this was the most profitable amount. We do know that it was very profitable even neglecting the value of the increase in the straw and the very striking effect on the clover which followed the wheat.

The experiment is a typical one for soils in the winter wheat belt and numerous others could be given showing results of just the same character and even more striking in profits.

The figures show how the lack of phosphoric acid limited the crop, and they serve to explain why bone gave such increases on these soils that for nearly a generation it was considered the only profitable thing to use.

In another series at a different place the amounts of the plant foods were varied, but the season was so unfavorable that the crop was limited by other considerations than plant food, the maximum crop being only about 13 bushels per acre and that of the unfertilized plots being only 2 bushels.

In these experiments the nitrogen is supplied from blood, the phosphoric acid from precipitated calcium phosphate free from gypsum, and the potash from muriate of potash, the purpose being to use materials exerting as little indirect effect as possible.

This matter is too often overlooked in planning such experiments, and for a considerable time the indirect effects may be so great as to mislead one who does not take them into consideration. Thus the gypsum in ordinary acid phosphate, amounting to about one-third of its weight and the sodium in the nitrate, may each release so much potash from zeolites in the soil that the plot with nitrate acid phosphate and potash may show little if any increase over that with nitrate and acid phosphate. Comparatively few experiments exist which have been conducted long enough and in such a way as to shed much light on the extent to which the indirect effects mask the direct effects.

In such cases one always turns to the admirable work at Rothamsted for help and the constantly increasing difference between the yields of plots 11 and 13 Broadbalk Field seem to show that the indirect effects are decreasing. The gypsum alone on plot 11 would theoretically release 90 pounds per acre of potash annually while the total annual application of potash on plot 13 is 100 pounds. The theoretical amount of potash that could be released by the bases in the minerals used on the fully fertilized plots at Rothamsted amounts to about 400 pounds of potash per acre annually while the potash applied in sulphate amounts to 100 pounds. While Director Hall has clearly pointed out the difference between the early years and the later, too many who use Rothamsted results to fortify their arguments simply take the average for the whole period and neglect to consider the results by decades.

Especially when we wish to secure indication of soil needs as promptly as possible should we take pains to use materials that will exert as little indirect effect as possible. By using blood as a source of nitrogen and gypsum free precipitated phosphates as the source of phosphoric acid we can remove most of these indirect effects and at the same time use materials easily secured and of high availability.

Another point that is never considered in planning the plot tests in the section under consideration is the marked difference in the fixing power of soils for plant foods and the firmness with which they hold them. This is roughly recognized in providing for an excess of phosphoric acid in commercial formulas but is seldom considered in plot tests.

The plot tests in most cases have simply been copied from plans made before the nitrogen gathering power of bacteria associated with legumes was understood and sometimes altered because of the injurious effect of the excessive nitrogen applications or too often abandoned altogether because the growth of the institution demanded the land for other purposes. The frequent changes in the staff of workers has also interfered seriously with both the conduct of the work and the interpretation of the results.

The conditions in the winter wheat section of the United States are such that large crops must be produced in order to realize a suitable return on the selling value of the land and the money spent for farm labor. The small grain crops are so related culturally with the clover crop that they are almost necessary in a rotation if we expect to utilize our most widely distributed legume as a source of nitrogen.

The chemical industries supplying plant foods and the purchaser of these products would both be greatly benefited by the inauguration at our experiment stations in the grain growing section of experiments properly planned to solve the question of the most profitable method of supplementing the plant food resources of the farms.

Up to the present time it must be confessed that the purely empirical methods of the fertilizer manufacturers have produced results that yield the farmer better returns than anything derived from the experiments started under the old system by the educational institutions in the grain growing section, but these are far from being the best obtainable. Both farmer and fertilizer manufacturer need the help of the educational institutions in the direction of securing facts relative to the most profitable methods of utilizing plant foods in the production of our great cereal crops —facts that will help and not discourage.

But such experiments must take into consideration

The kind of materials to use,

The avoidance of indirect effects,

The right methods of application,

The question of the most profitable amount, and finally

The rational interpretation of the results obtained.

German Kali Works, Chicago, Ill.

# Federal Control of International and Interstate Waters.

By Barton W. Evermann.

Mr. President, Members of the Academy—I shall talk a very few minutes on this subject. The idea of federal control in matters pertaining to fisheries and game is a recent one, and one of recent and gradual development. I think perhaps the idea was first advanced in connection with the control of migratory birds. Ornithologists and others interested in the preservation of birds realized a number of years ago that the state laws of the various states were inadequate for the control of migratory birds. A bird today is in Louisiana or Alabama, tomorrow in Tennessee, next week in Kentucky, then Indiana, then Michigan, and the game laws in the different states are different. In some of these states there would be a law adequate for the protection of migratory birds as they went north or south, but in the next state into which they went there would be no law, so that migratory birds received very inadequate protection or no protection at all.

The first bill that was introduced into Congress that had any bearing on this question was introduced by George Shiras III, of Pittsburg. In this bill he proposed that the Federal government should take over the control of the regulations for protecting migratory birds. A little later the idea expanded and Mr. Shiras introduced a bill in Congress providing for the protection of migratory fishes. His attention had been called to the fact that in the Atlantic coast States there is no law adequate to protect the shad and other migratory fishes. The difficulty existed in all of the streams where migratory fishes came, but particularly in those streams which lie between two States and which are controlled by two or more States. The Potomac River was taken as an illustration. The laws of Virginia on one side and Maryland on the other were never the same, and at the same time it was legal to fish in one State and illegal in the other. The inevitable result was a series of evasions of the law by the fishermen of these States.

The Columbia River is another illustration, perhaps the most serious of all. There you have Montana, Idaho, Washington and Oregon, all con-

cerned in the Columbia River. Idaho and Montana are not seriously interested in the salmon, but Washington and Oregon are both vitally interested in the salmon fisheries of that stream. But these two States have never been able to agree upon concurrent legislation which adequately protects the fisheries, and things have gone from bad to worse. Two years ago an effort was made by certain people interested to restrict the taking of salmon in the upper Columbia by cutting out the use of certain kinds of apparatus. This matter was referred to the people in Oregon, and at the same time those who were interested in the fisheries in the uppr Columbia had a similar question submitted to the people stopping fishing in the lower river, and a very curious result followed. The people said it would be a good thing to restrict fishing in both parts of the river, so both amendments carried, and the inevitable result followed that neither is enforced, illustrating very clearly the impossibility of two or more States agreeing upon adequate measures in questions of that kind.

Then the question came up as to the control of the fisheries in international waters. The question there has for many years been a serious one, particularly on Lake Erie. That lake has abutting on it four States on this side of the line—Michigan, Ohio, Pennsylvania and New York—and the province of Ontario on the other—five political units that are all interested in the fisheries of Lake Erie, and no two having the same laws, so that at one time it would be legal to fish at a certain distance from the shore and with certain apparatus off that narrow portion of Pennsylvania which fronts on Lake Erie, and just beyond that narrow strip in Ohio or New York it would be illegal, and there was constant difficulty to keep the fishermen of one State within the strip in which they had a right to fish; and the regulations on our side were in every case entirely different from those on the Canadian side, so that friction followed there. It was impossible for the individual States to handle this question, and in that way the question of federal control came up.

In addition to these questions, and of more recent development perhaps, has come the question of the desirability of federal control of interstate waters and other waters in the matter of public health. We have a good illustration of the necessity for this in the Potomac River. Washington City has sometimes suffered from an epidemic of typhoid fever, and investigation has shown again and again that the source of infection was not in the District of Columbia, but was brought from some place

else; and carrying the investigation still further it has been proved on more than one occasion that Cumberland, Maryland, is responsible for at least some of the typhoid epidemics at Washington. The waters of the Potomac become infected at Cumberland, many miles above Washington, and the germs are carried from there and people infected. The District of Columbia, of course, is absolutely powerless in the premises; it can do nothing. The State of Maryland has done nothing, and the outlook is not encouraging. I do not believe Maryland will do anything to remedy the difficulty. It affects not only the District of Columbia, but every town between Cumberland and the District of Columbia, so that in that case the matter of public health is concerned in Maryland, the District of Columbia and Virginia.

A little more than a year ago the United States and Great Britain entered into a treaty providing for the appointment of an International Fisheries Commission, with power to draw up regulations governing the fisheries in international waters between the United States and Canada. That treaty specified the waters—from Passamaquoddy Bay on the east to Puget Sound on the west—taking in all of the Great Lakes except Michigan. As I see it, the principal point, the principal necessity for that treaty was to secure a set of uniform regulations for these waters. Under it, fishing on one side, in Canada, and in Ohio, Pennsylvania or New York, on the other, as far as Lake Erie is concerned would be the same. There would not be the conflicts which now exist. It does not seem to me that that treaty was necessary in order that the Federal government might take control of the fisheries in these waters, and for some reasons it would have been better if they could have brought about federal control of fisheries in these waters without entering into a treaty between the two countries. There may be some little risk in giving a foreign nation a hand in determining what shall be the regulations in the waters of Ohio, of Michigan, Pennsylvania or New York, and make it impossible for the United States to change the fisheries regulations on our side of the line without the consent of another country. But that may be laid aside as a matter of secondary importance.

One of the first men to become interested, to recognize the importance of the question of federal control in these matters was George Shiras III, a grandson of Chief Justice Shiras, an angler, sportsman and all-round naturalist, who is very much interested in the preservation of game

and migratory birds. He first become interested in the protection of migratory birds, then fishes, and then in the larger question of all animal life in the streams which cannot receive adequate protection from individual States, and from that he has taken up the question of pollution of streams, and it has been shown by him and by others that the Federal government always had power to control interstate and international waters in all matters of navigation and fisheries and public health, because these three questions are larger than the interests of individual political units. The Federal government has exercised that power in the matter of navigation, but it has never exercised it in matters of fisheries or public health—the pollution of streams. But that it has that power and can exercise it whenever it wishes to do so, and that it is perfectly constitutional, I have no doubt in my mind, and I think the time is coming soon when it will be done. In this day when the question of public health is being agitated and considered so seriously, and when we understand more fully than we ever did before the sources of disease epidemics, when we realize more and more that the question is broader than the boundaries of a single State, it is clear that this question is a question which must be handled by the Federal government and cannot be handled by the individual States.

In the treaty between the United States and Great Britain, as you doubtless know, President Jordan was appointed commissioner representing the United States, and Prof. Edward E. Prince to represent Canada, and these two commissioners have gone over the boundary line from St. Johns to Vancouver, and at the end of last May they submitted their report to the respective governments, a report embracing a set of recommendations—some sixty-six in number—which they hope will control in a satisfactory way the fishing in international waters. That report will be made public, doubtless, soon after Congress meets. It will go to Congress and to Parliament, where the necessary provisions for enforcing these regulations will be provided. As it now stands, Canada already has the machinery which is needed to enforce the regulations on her side of the line. She has a very efficient system of patrol, facilities and men and means to enforce her fisheries regulations far better than they are enforced on this side of the line, particularly in Puget Sound. There is no such machinery on this side of the line for enforcing any set of fisheries regulations, because the matter has been and is now in the hands

of the respective States. Each State has its own machinery; but under the terms of the treaty it would seem that the Federal government is morally bound to provide the necessary machinery for doing as well on this side of the line as Canada is doing on the other.

Now, if it turns out, as we believe it will, that this is the beginning of federal control in all of these large and important streams, then will come federal control not only of international waters, but interestate streams, and in all matters of pollution of any and all streams.

Mr. Shiras cites a number of cases: The State of Missouri vs. Chicago Drainage Canal, in which the decision of the court showed that the question is one larger than the State of Illinois and the State of Missouri, and that the Federal government must take it up. A similar case, Kansas City vs. The State of Colorado, the decision of the court pointed to the same view. And there is every reason to believe that the Supreme Court will uphold these decisions.

Bureau of Fisheries,
Washington, D. C.

# The Speed of Migrating Salmon in the Columbia River.

By Chas. W. Greene.

(Abstract.)[1]

In the solution of this problem I devised a scheme whereby individual fishes could be given individual tags that would render identification absolutely certain if the fish should be recaptured. This plan was nothing more or less than the use of the conventional stock-marking aluminum buttons. These buttons are light and cannot be torn apart and they carry serial numbers on one face; on the other can be placed such special marks as one may select.

On August 14, 1908, I marked fifty-nine fish at Sand Island, just within the mouth of the Columbia River. These fish were liberated in the river in the hope that some would be retaken, and thus we might glean the story of their migration. The fish were marked by inserting numbered buttons through the caudal fin.

Seventeen of the fifty-nine fish liberated were retaken and reported to me; sixteen buttons were also returned to me. The fish were retaken along the river from a point four miles below where they were liberated up to the Dalles of the Columbia, just below Celilo Falls, a total distance of two hundred and fourteen miles. Near the upper limit quite a number of fish were taken and six of these had traveled a distance which, when rated, gives an average individual speed of from six and one-third to seven and one-half miles a day.

The following table is constructed to show the actual time from liberation to recapture, the distance covered, the probable time consumed in the straight-away run on a basis of the speed of number 76 (seven and one-half miles), and the days unaccounted for. My view is that these unaccounted days are chiefly spent in the lower estuary of the river in becoming acclimated to the fresh water.

[1] This investigation was undertaken in cooperation with the United States Bureau of Fisheries. This abstract is published by the consent of and with the approval of the U. S. Commissioner of Fish and Fisheries.

| Species and Number. | Distance Traveled in Miles. | Days Out. | Days Required to Cover the Distance at a Speed of 7½ Miles a Day. | Days Unaccounted for, i. e., Available Acclimatization. |
|---|---|---|---|---|
| Silver.... 76 | 210 | 28 | 28 | 0 |
| Silver.... 75 | 210 | 29 | 28 | 1 |
| Silver.... 89 | 210 | 30 | 28 | 2 |
| Silver.... 79 | 210 | 33 | 28 | 5 |
| Silver.... 97 | 210 | 33 | 28 | 5 |
| Steelhead....124 | 210 | 33 | 28 | 5 |
| Chinook.... 80 | 15 | 11 | 2 | 9 |
| Steelhead.... 98 | 210 | 52 | 28 | 24 |
| Steelhead....125 | 70 | 35 | 9 | 26 |
| Chinook....123 | 15 | 31 | 2 | 29 |
| Silver.... 87 | 70 | 57 | 9 | 48 |
| Chinook....113 | 4 | 6 | 0 | 6 |

University of Missouri,
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# Thought Stimulation: Under What Conditions Does It Occur?

By Robert Hessler.

This is a subject of interest to nearly every one, but more especially to educated persons, as I found in discussing it with several hundred individuals. In a general way one may divide human beings into two classes: the educated and the uneducated. The uneducated usually pay but little attention to what is going on in the mind, what sort of thoughts they have, while on the other hand those who write or otherwise utilize their thoughts may pay much attention to the subject. Indeed, the latter may at times be worried because they can not think and cannot write, or because they "run out of" thoughts and vainly "rack their brains" for new ones. In the very beginning we must distinguish clearly between getting new thoughts or new ideas and the ability to write them out. In other words, to get the germ or plot of a story and then to write out the story to best advantage are two widely different things.

The difference between these two classes of individuals is shown very strongly in the matter of dreams. The ignorant pay considerable attention to their dreams, but only from the standpoint of "What does it mean?" They look upon a dream as an omen, while a writer may utilize a dream as a plot for a story, the dream being of actual value to him. Poets constantly tell about their dreams and of having dreamed. Again, we see this difference in attitude in the matter of the subconscious or automatic action of the mind, especially at night. There may be a great rush of thoughts. Many worry simply because they are unable to sleep on account of the "curious thoughts," while a writer may jot down a number of them and utilize them in his work.

The subject of thought stimulation may be studied from different standpoints, depending on the individual's occupation and training and the object of his investigation. Thus, the psychologist may approach it from a standpoint entirely different from that of the neurologist or of the alienist, while the viewpoint of a story writer may differ from all others. My standpoint may quite naturally be said to be mainly that of a physician interested in a study of chronic ill health as distinguished from ac-

tual disease. Many of the symptoms occurring in chronic ill health relate to disturbances in mental functioning, and hence must be given considerable attention.

If a physician desires to study normal individuals, that is, those who are neither sick nor diseased, he must go after his material. And here I might say that some, knowing my profession, have accused me of "talking shop." It is of course only those in search of a physician's services who come to him—and this paper may therefore be regarded as that of a seeker after knowledge, that is, a plea for more data from these in health. I hope that when it appears in the published proceedings some at least will take sufficient interest in the matter to give me their experiences and observations.

In regard to what I say here, it should be understood that this is simply a short abstract of a longer abstract. If I were to bring together all my data, and especially my case reports, they would make a large volume.

CLASSIFICATION OF DATA. For the purpose of classification as well as for convenience of study, I have divided my notes under several general subheads, as follows:

1. Simple observations on thought or mental stimulation before my days of medical schooling, such as any one not paying special attention to the subject might make.

2. Early days of medical practice. These notes are also rather simple, for it should be understood that in times past a medical student's attention was not called to the subject of mental influences.

3. Notes gathered while working among the insane.

4. Travel notes while in Europe, among them many relating to the environment of noted men and women, particularly of writers.

5. Notes, covering the last ten years, based on a systematic study of people in ill health, as distinguished from those afflicted with well-defined diseases. The bulk of my notes relate to this class of individuals.

6. Notes obtained from individuals who may be regarded as healthy, that is, not complaining of symptoms of ill health.

7. References to the literature, a comparatively small amount of data, chiefly incidental references found in biographies. This phase of the subject has been neglected, as it requires access to extensive libraries.

References to childhood are here omitted; my work concerns adults only. But we need only think of nightmare to realize how profoundly the mind of the child is influenced at times. I shall go over these subheads ery briefly, following the above classification.

**People.** Some people, or minds, with whom we come in contact stimulate us, just as there are those who depress us and many who do not affect us at all.

**Books.** These may also be classified according as they do or do not set us to thinking; some books act as decided mental stimuli.

**Dreams.** Dreams may be a source of mental stimulation to the intellectual, who may get some new ideas and utilize them. The ignorant dwell chiefly on the significance of dreams as good or bad omens. One can hardly realize what an important factor dreams are in the life of some people. This topic will be considered a little more fully later on.

**Food and Drink.** These have more or less influence on our well being and our thinking. One need only think of what often occurs after eating a late lobster salad or a welsh rarebit, when the thoughts are usually anything but agreeable. There is an old saying, "Who drinks beer, thinks beer"; and another, "One is what one eats."

**Alcohol.** Some know from personal experience whether alcohol excites or depresses the mind; certainly all have noticed the effects in others, how some individuals become greatly excited, with an active flow of words.

**Tobacco** should also be mentioned. Just how much truth there is in the claim of some men that they can think best while smoking or chewing is a question.

**Anger, Jealousy, Resentment,** or **Grief,** etc., may act as powerful stimuli.

**Fright** and **Danger** should also be mentioned; there may be a great rush of thoughts at what seems to be a critical moment.

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**Fever Fantasy.** Those subject to colds and feverish conditions may have noticed in themselves the abnormal stimulation of thought at such times. The physician cannot avoid noticing it, especially in those delirious on account of fever.

DRUG STIMULATION. The most common is that of opium or its alkaloids, cocaine coming perhaps next. Hasheesh effects I have not observed. Not all persons are stimulated after the fashion of DeQuincey. Some brains are stimulated but little or not at all. The same is true of alcohol. The effect depends, moreover, largely on the dosage, varying from a more or less transient stimulation to complete stupor. It should be kept in mind that to a large extent anodynes that depress, such as acetanilid, are now used in place of opium.

COFFEE. This is an active stimulant to some; many know that it will keep them awake at night, as night nurses. Some persons say coffee makes them dream. Literary workers may be actively stimulated by it, their thoughts flowing freely after its use.

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MANIA. An individual delirious in acute mania is a sight never to be forgotten. The delirium may continue for days, even for weeks, until the body is physically exhausted. Compared with this, the amount of mental work an ordinary brain worker does seems insignificant, and the idea of nervous prostration from mental overwork is made to appear ridiculous.

RECURRENT MANIA. This recurs at intervals, depending on the individual, after days, weeks, months, or even years.

ALTERNATION OF MANIA AND MELANCHOLIA. In this there are periods when the mind is very active, followed by periods of the opposite extreme. One of my insane patients during a period of exaltation had *Cacoethes scribendi*, the mania to write, and wrote me his autobiography; it would form a fair-sized book if put into print. He wrote continuously, did not even want to take time for meals or to sleep at night.

CHRONIC MANIA. In this condition many individuals see visions and hold imaginary conversations; at times the brain is very active.

DEMENTIA. At times when there is some disease producing fever there may be a transient lighting up of the mental faculties in dements, subsiding again with the subsidence of the fever. A study of such cases often sheds light on the mental processes in the normal, or sane.

EPILEPSY. Epileptics about the time of an oncoming seizure may have active mental stimulation; the fact that some see visions is well known.

As a rule those confined in the hospitals for insane are quite demented, though there may be a transient mental improvement during or following some acute disease.

One of my unique experiences was the observation of the great mental improvement following the injection of erysipelas antitoxin[1] in an epileptic who was greatly demented; this mental stimulation, however, was only transient, subsiding on withholding the remedy, which proved too costly for continued use; in time there was a complete relapse.

KATATONIA. Under this head I could write some lengthy accounts relating to mental stimulation from the use of desiccated thyroids.[2] Individuals who had been practically dead, both physically and mentally, had a veritable return to life under the use of thyroids.

THYROID MEDICATION OR STIMULATION. The above experiments were continued with different classes of patients to find out the limitations or usefulness of the new drug. This was quickly found.[3] In a chronic maniac it brought on acute maniacal disturbance and had to be discontinued. On the other hand, in individuals who were very dull and stupid on account of myxedema[4] all that was required to restore normal activity was the use of this remedy.

REDREAMING DREAMS. A personal experience while still living among the insane first directed my attention to dreams and the part they play in daily life. My experience in dreaming a dream over and over again during an attack of sore throat seemed so odd to me that I looked up the subject in the literature, and since then have questioned hundreds. I found nothing in the literature, and until recently did not meet any individuals who had had a similar experience—for this reason I gave a brief account in the *Psychological Review* for November, 1901. It may be added that while I dream much, but few dreams, comparatively, stand out vividly and are remembered next morning. An interesting study would be to seek the causation of dreams, why at times one dreams much and then again very little; likewise why certain periods of one's life rather than others are picked out, so to speak, by dreams.

DISEASE INFLUENCE ON MENTAL STIMULATION AND DREAMS. Here belongs a number of notes on cases in which the stimulating influence was

[1] Epilepsy and Erysipelas. Journal Amer. Med. Assn., May 14, 1898.
[2] Thyroid Medication. Indiana Medical Journal, June, 1896.
[3] Notes on Thyroid Medication. Ind. Med. Journal, Feb., 1898.
[4] Myxedema. Indiana Medical Journal, June, 1904.

noticed, as for instance in tonsillitis, when the mind becomes very active, with a great rush of thoughts, but without ability to hold them. After an attack of acute illness there may be a "clear brain" with active thinking. This can be explained by assuming that the brain was rested while the body was sick, or that it was stimulated by the disease or sickness, or by returning health, and now has a new set of thoughts.

Tuberculosis acts in many as a stimulant, producing especially cheerfulness and hopefulness, just the opposite from the next.

Acute Dyspeptic Attacks, as after the proverbial lobster salad. Here almost invariably the thoughts and the dreams are disagreeable, oppressive. Often it is less a question of the kind of food than of conditions under which the food is eaten. In the case of the lobster salad, the most favorable condition under which it is likely to produce disagreeable thoughts or dreaming is, in the opinion of some, a midnight lunch after attending a theater.

Chronic Dyspepsia. This to most of us brings up thoughts of pessimism, the effects thus standing opposite to those of tuberculosis. As a supposed classical example, Carlyle might be mentioned.

Atmosphere, the Air of Places. Literary people speak of the influence of atmosphere, but this may not at all refer to air conditions. On the other hand, physicians since the days of Hippocrates speak of the air of places. From a study of the subject one might almost come to the conclusion that the locality, the environment, has as much influence on thought stimulation as on the production of ill health and disease.

War Times. In my chronological account are some data relating to a friend whose regiment was called into camp on the breaking out of the Spanish-American War. The event was a great thought stimulant to him, especially when lying awake at night.

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Travel. Next in order comes a mass of data based on a year's travel in Europe. The value of travel as a stimulant to the mind is recognized by everybody. The following is taken from my notes relating to this period:

"One day, at Heidelberg, I dropped into an inn for a bite to eat. I was going to sit down before a long empty table, when I was informed that it was a Stammtisch; that meant I had to take a seat elsewhere. While eating my modest meal, there was a rush of thoughts concerning the influence of the Stammtisch on the life of German thinkers, especially

college professors, who frequently meet about such a table to exchange ideas, or get new ones, or both. Then my thoughts went to England, to its old coffee houses and the influence on the English writers who met there. That in turn brought to the mind the relative merits of beer and wine and coffee as aids to thought stimulation, and this again brought up the thought of the influence of tobacco smoke, whether this at bottom had anything to do with the matter, and that again brought me back to America, to our newspaper offices, where reporters often work in dingy offices densely filled with tobacco smoke and where many of the so-called 'pipe dreams' are concocted."

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HEALTH, ILL HEALTH, CHRONIC ILL HEALTH, DISEASE. During the last ten years I have been occupied more especially with adults in chronic ill health, as distinguished from real disease, and very naturally I have followed the subject of thought stimulation among this class. There is one very practical aspect, one, however, that is largely neglected by the average practitioner of medicine; that is, long sleepless nights during which the mind of a patient may be thinking all sorts of thoughts, usually disagreeable; if there is sleep there may be much disagreeable dreaming. The physician who is able to give patients of this kind restful nights is usually accomplishing something that his predecessors failed to do.

Individuals in chronic ill health often have very active minds and react acutely to certain drugs, such as opium, alcohol, caffeine; similarly to the salicylates, which are largely used in counteracting infection and inflammation. Many react acutely to the influence of travel. Thus while travel at home may disagree, travel in a foreign country may be beneficial. One can, of course, readily understand how in the case of literary persons one country may be preferred to another. But even common people who do not lead much of a mental life may notice the influence of travel, as when a farmer living in isolation complains of active dreaming or of restlessness at night after a trip to town. Among my case reports are at least four in which there was active stimulation of the mind while traveling on railways—in one case the thoughts or ideas were used in literary work. It may also be said that individuals with lively minds, literary people generally, react acutely to their surroundings, or to influences that scarcely produce an effect on the average man.

During the past few years I have been trying in my practice to distinguish between individuals who lead an active "Seelenleben" and those

who do not. In a general way I can divide my cases (whether active minded or not) into four groups according to their ill health.

(a) Catarrh Victims, especially those subject to common colds and sore throat accompanied by disturbance in temperature, febrile condition, with more or less "fever fantasy," when all sorts of thoughts rush through the mind. If the individual is a writer and not too ill he may jot down some of these thoughts and utilize them. In some a recumbent position is an additional stimulating factor, and, indeed, people in health can often think best when reclining. One of my friends explained it by saying: "The pressure is equalized when lying down, there is less blood in the feet and more in the brain."

Catarrh victims may or may not be cheerfully excited—those infected with tuberculosis may be very cheerful and hopeful, the opposite of the next.

(b) Dyspeptics as we all know are usually pessimistic. One of my friends has said: "Beware of the literary critic who has dyspepsia or an acute dyspeptic attack, for he will see nothing to praise in your work or effort; all is gloom to him and mankind is going to the bow-wows." The depressed mental state may not last long in an acute attack, just as in the case of the boy who has colic from eating green apples, who thinks he is going to die, although he will be as well as usual the next day.

(c) So-called neurasthenics, known also as neurotics, and "the nervous." As a rule this class reacts acutely to environmental influences, and at night there may be insomnia with the mind actively at work. As to actual work, individuals vary greatly. Many have large thoughts but produce little; some are simply regarded as dreamers. What is commonly regarded as brain tire may really be motor tire; the brain is active enough, but there is no desire or little inclination for physical exertion necessary to write out the thoughts—a mental overstimulation with a motor paralysis, so to speak.

I have notes on one case, a man who would ordinarily be regarded as a neurasthenic, who dreams much and gets new ideas in his dreams, jotting them down in the dark at night, in bed. But frequently he finds in the morning that he has no notes, for, after a dream that he wants to record, he dreams further that he is recording it or has made an entry on his scratch tablet, and then sleeps on; all has been a dream. Sometimes on awakening he retains an indistinct idea of the dream which he wanted to record.

The influence of environment may be very marked in this group, as already mentioned. Some men can do their best work in the city, others in the country. I have a curious account of a writer who habitually ran out of ideas and then went to the nearby large city to spend a day, or rather night, for he would lie awake in the dark, in his room at some large hotel, filling scratch tablets with all sorts of thoughts or ideas that came to him. It would be interesting to know whether there was any marked change in blood pressure, whether he may not have belonged to the next group.

I shall refrain from citing more such cases, for to make reports valuable they should give a lot of details, or we may be wholly unable to draw conclusions regarding possible causes. In a general way it may be said that the more details in a case report the better.

(d) A group of cases that may be called cardio-vascular, in which there are disturbances in the blood pressure. At times of a high blood pressure there may be great mental activity. Brief mention may be made of a few cases.

Mrs. A. Middle-aged woman with a persistently high blood pressure, rarely under 200 mm, and often much above that, even to 250 mm. Complains of the mind being very active, all sorts of "komische Gedanken" passing through the brain; but at times of unusually high pressure the thoughts are anything but comical, the "Gedankenflucht" being the opposite; she at times fears enacting a tragedy. When I add that my own pressure runs from 100 to 110 mm, the significance of a pressure of 250 mm will be better understood.

Mrs. B. Elderly woman, gloomy and worrying thoughts both on account of ill health and possible financial difficulties. To distract her mind, to change the trend of her thoughts, her relatives nightly took her to a crowded revival meeting, but it was quickly found that conditions grew worse, and that the rush of thoughts seemed to prevent sleep altogether. She came to me and I found a high blood pressure. Simple medication and remaining away from the meetings caused the high pressure to disappear within a week, and the mental disturbance to subside, followed by a philosophical state of mind with cessation of worry.

Neither of these two individuals is intellectual; they do not utilize their thoughts.

Mrs. C. Middle-aged intellectual woman. Great rush of ideas at times of occasional high blood pressure, especially at night, often prac-

tically sleepless on this account. In the day time felt too fatigued, tired out, to be inclined to exert herself physically, but the mind would perhaps be very active. Often had "bright thoughts" at night and wanted to get up and jot them down, for she was unable to recall them the next morning, but her physician had told her not to do this, as it would aggravate her insomnia. When she came to me, I promptly advised her to jot down her thoughts, that with a little practice she could do this in the dark; at the same time I instituted measures to reduce the blood pressure — and when the pressure went down the automatic action of the brain ceased and sound sleep returned. How to bring down a high blood pressure is a medical question that need not be discussed here.

Mr. D. Middle aged man in whom a tendency to increased blood pressure gradually developed, along with much dreaming at night and subconscious mental activity, the thoughts coming at such times being utilized in his work. Problems and matters awaiting solution would be taken up and worked out at such times. This subconscious activity was always orderly, entirely different from that of dreams, for in the latter there were all sorts of incongruities and anachronisms. A change in environment caused the high pressure to subside and with it the subconscious mental activity, but the dreaming continued as formerly. Now and then there is a period, or it may be but a single night, of automatic activity, and the question is to find out the why and the wherefore of this activity.

Mr. E. The most literary man in a small community; past middle age; mind always at work. Came to me complaining of symptoms of ill health. I suspected cardio-vascular disturbance and on examination found a high blood pressure. I at once proposed a systematic examination, with health supervision. But to be literary does not necessarily imply the possession of good common sense, and instead of following my advice, given him at length, he adopted an easier and simpler course; he changed doctors. He went to a man who merely gave him a little medicine. A short time ago he died suddenly of cerebral hemorrhage.[1]

Ordinary people when they have a rush of thoughts at night may simply worry because they are not able to sleep, whereas the brain worker who utilizes his thoughts may welcome at least an occasional such rush

[1] There is a possibility that in this case arterio-sclerosis had set in, but I am inclined to believe there was none at the time he came to me. It should be kept in mind that in this paper I am excluding children and the aged, as well as those afflicted with well defined diseases or pathologic processes.

of thoughts, because it may furnish him material, data, plots. He may even seek to bring about this condition, or what is commonly called "inspiration." In this connection I might mention one case which may shed some light. A middle-aged literary woman had been complaining of disturbed heart action, marked especially by arrythmia. In order to correct the difficulty, her physician prescribed digitalis in larger doses than is usual. In a short time her mind became very active, with sleeplessness at night and with a great rush of thoughts. She then came to me and I promptly had her discontinue the digitalis, when the mental excitement subsided. The supposed heart disturbance itself was treated by methods other than drug treatment.

To what extent high blood pressure is a factor in thought stimulation in normal individuals I am unable to say. To study that will require "material." If, as earlier stated, the physician wants to study those in health he must go to them, and seek out those whom he thinks suitable for his work. Moreover, a physician never has that complete control over his "material" as the biologist. He can take up or leave off work at any moment; the physician must get the consent of his patients. Even the hospital physician has a great advantage in this respect.

It would seem a natural and simple inference that the increased circulation in the brain stimulates the cells, and thereby stimulates thought—and then at once the question arises, What brings on increased blood pressure?

**Borderland Cases.** Just where the normal shades off into the abnormal or where "perfect health" changes into "ill health" is often difficult to determine. There is no norm, there are no standards: what agrees with one may disagree with another. I will mention a few more factors which in some individuals play a role in thought stimulation.

**Music.** The mind or imagination of some people is strongly excited by music. When one critically studies cases he may be able to make distinctions between the influence of grand opera and rag time music, and whether the music is heard indoor or out of doors, as on a street corner or in a park.

**Theater.** Attending a play may bring on a lively "play of the imagination."

**Church.** A merchant once told me that he did his best business thinking or planning while apparently listening to a long sermon. And I

know of a college student whose thoughts were most active while "listening to a sermon." Such stimulation is known to but few, while the opposite, drowsiness, is known to nearly everybody. Perhaps the "constitution" has something to do with it. I have notes on a preacher who gets his ideas for his next sermon a week ahead. If he fails to get them on Sunday night, he probably gets them at the time of the midweek prayer meeting. Local option meetings also seem to excite some—is it the enthusiasm?

STORMS. Among my case reports are some of individuals whose minds were set agoing during the prevalence of a storm; if at night, there was much restlessness and sleeplessness with a rush of thoughts. An inquiry into details often leads to curious results.

WEATHER CHANGES should also be mentioned. The state of the weather is by many supposed to have an influence. I should especially like to hear from those who have made any observations along this line.

BOOKS. Books, as a source of thought stimulation or of inspiration, are generally classified as good or bad, ancient or modern, new or old. To the average reader a book is simply a book, but those who utilize their thoughts or bright ideas may be able to make distinctions. Reading between the lines, an individual with a vivid imagination may get all sorts of new ideas, he may get more out of them than the author put in.

LECTURES differ greatly in their stimulating influence. To some an occasional lecture may be helpful, while repeated lectures may fail to stimulate, or one may say there is overstimulation and the mind fails to retain the impressions. We all know how the lectures of instructors vary; some stimulate the students, others do not.

BARBER-SHOP INFLUENCES. One of my old patients, who lived at home all the time, went once a week to the barber shop, and then complained of insomnia with much dreaming at night. (But to make the story more complete it should be added that he was a chronic consumptive and that much coughing accompanied the insomnia and dreaming—some might regard this as a relationship of cause and effect.)

I recall a statement in a French reader, "Nothing refreshes the mind like having the hair dressed." A man is supposed to have made the remark—I mention this here as a possible factor in mental stimulation in

women, as they often spend much time in dressing the hair. Perhaps that statement is on a level with that of the poet who spoke about "scratching the head, thinking the thoughts would come," etc.

EXERCISE may be an essential to a writer or sedentary thinker, as for the man who writes all forenoon and puts in the afternoon walking, riding, rowing, gardening, etc. Here one would have to distinguish between properly working up ideas and getting new ones, between resting the brain by a different occupation and getting new thoughts while so occupied; the new thoughts may perhaps come involuntarily while physically employed.

BATHS of various kinds seem to be a stimulant to some persons.

"BEING IN HARNESS" is an important factor, as in the case of the business man who could not think, could not plan, while on a vacation, but the moment he returned to his dingy office his mind became very active. One man of affairs told me he would rather wear out than rust out, meaning that although he felt better physically while away from his old occupation his mind was dull; he would rather not feel so well bodily than to have ennui and boredom.

### SUBCONSCIOUS MENTAL ACTIVITY.

Perhaps the most interesting phase of the whole subject is that of so-called subconscious cerebration, with its various synonyms, such as automatic cerebration, unconscious cerebration, etc. This form of mental activity is to be clearly distinguished from conscious activity on the one hand and from dreaming on the other; it is neither. Thus, while writing these notes, an old patient to whom the question was put gave me a good illustration.

This woman is a clerk in a county treasurer's office (I am not naming the county). Ordinarily she does not dream, or so lightly that few of the dreams are recalled the next morning. She has what may be considered good health, but at times does complain of some minor ills. Twice a year she works under great stress, at taxpaying time, when from early morning till late at night she is at the office, taking in money and receipting for it. After a day or two of this hard work she continues the work at night, "in her mind," to the exclusion of sound or refreshing sleep—the mind automatically and in spite of all her efforts to prevent going over and

over the work of the day. On account of the loss of sleep, etc., she begins to suffer in health, and feels sure that at times if there were a few more days of it she would break down. But she admits one advantage of this automatic action of the mind or brain: Errors are constantly occurring, and when the books are balanced at night no one can account for the various discrepancies, and, of course, there is worry. Now in her "night work," during this automatic cerebration, she generally "sees" just where the discrepancies are and the next morning is usually able to make the corrections promptly.

She has some well-defined ideas regarding causes, that is, of the conditions under which such activity comes on, and I shall consider her remarks later on in summing up "causes" and "supposed causes."

Asked about dreams, she said they occurred in the winter time, rarely in the summer—the exceptions usually being times of actual illness.

Another patient told me that as a boy in school he worked out his mathematical problems while in bed at night. After he left school this form of mental activity largely disappeared and now only occasionally returns; he utilizes it in planning his business affairs.

Insomnia. After a wakeful period at night, perhaps of an hour or two, there may gradually come repose, and then when one is about to fall asleep, subconscious mental activity may come on with a flow of thoughts, perhaps valuable in one's work. Then comes the conscious thought, "If I don't jot down these thoughts or ideas they will be lost: if I do write, then the composure to sleep will disappear and I will again be wakeful and sleepless. Shall I write or not? Shall I put the thoughts on paper or get the sleep?" While undecided, sleep may come on, there may even be a dreaming that the thoughts have been written: the mind is relieved and deep sleep follows. In the morning nothing is remembered of the train of thoughts. If, however, they were written out, then on awakening the whole occurrence likely comes vividly to mind, or at least there are notes more or less clearly decipherable. This may also occur in the morning when one is about to turn over for another nap, and then this mental activity is confused with dreaming, but the coherency of ideas enables us to distinguish.

Sleepless nights of active minded people who utilize their thoughts are often due to the fact that they do not want to let go of the thoughts that come. They lie awake, thinking about them, or they will be kept

awake by the very act of writing them down. When the mind is relieved and sleep is about to come, there may be another train of thought, and this too must be disposed of. This may recur over and over, and as a result there is a sleepless night. Insomnia is usually considered the bane of the brain worker, but perhaps after all it has its compensations.

Some individuals can distinguish very clearly between dreaming and subconscious mental activity. Some who utilize their thoughts refer to the latter as "inspiration," and in their attempts to bring on such a condition have tried all sorts of experiments. In reading biography one at times comes across statements that seem to refer to this condition of mind, as when Voltaire or Pope in the middle of the night called for his clerk or stenographer to take down a train of thought. This form of mental activity occurs in all kinds of persons, but as already mentioned is most marked in brain workers. The question naturally arises, What is back of it all? What produces this form of mental activity? By gathering a large mass of data one may be able to arrive at some conclusions. One can not solve the problem from a study of books, it must be studied in living persons whom one can question about details and antecedents.

Here again my own observations have been confined mainly to those in ill health. To what extent automatic mental activity is a question of medicine and to what extent a problem in psychology may largely depend on the individual studied, as well as on the student—on his knowledge and purpose. But we should not forget that the modern psychologist studies and investigates largely by the use of instruments, in his laboratory.

To study the influence of blood pressure requires the use of a sphygmograph, and that means that the study of thought stimulation due to the changes in blood pressure is beyond the man who makes but simple observations. The man not connected with a laboratory might, of course, seek out a physician who makes blood pressure tests and would interest himself in the subject.

On the other hand, auto-observations of what is going on in one's own mind are or can readily be made by any one who will take the trouble to observe, no apparatus being required, unless it be a watch or clock to note the time of day or night and a fever thermometer in the case of those who have "fever fantasy"—which may or may not be distinguishable from the mental activity unaccompanied by fever or dis-

turbance in the temperature of the body. At times the mental stimulation may be wholly out of proportion to the rise of temperature, and I have had cases where there seemed to be a high temperature, judging by the redness of the face and the complaints of the patient, and yet the thermometer failed to reveal any elevation of temperature. One has to distinguish between "feeling feverish" and having a real fever, that is, an actual elevation of temperature.

Just now a fad has spread over the country which gives undue importance to this form of mental activity in the treatment of ill health and the cure of diseases. It would seem that there are two kinds of psychotherapists, the real and the pseudo. The former limit themselves to so-called neuroses and functional disturbances, while the latter ascribe subconscious mental activity to practically everything—except perhaps to the healing of broken bones.

I have already referred to the fact that some individuals make sharp distinctions between dreaming and subconscious mental activity or subconscious cerebration. I myself believe these are two different processes but one will have to give close attention to what is going on in the mind to enable him to discriminate. As to the possible existence of a "subconscious mind," as an entity, that is another question. Perhaps it is synonymous with the "soul" of the old philosophers.

Questioning About Dreams. In questioning people about dreams one quickly learns to divide dreamers into three classes.

There are those who "wonder what it means," who are constantly speculating on the significance of a dream. Some will tell of having heard some one telling of seeing a certain event in his dream and found that very thing to have actually occurred at the time and place indicated in the dream. They will tell of it in detail, if one listens, and then ask. Now how do you explain that? Personally, I have never had such a dream, one in which I "saw in my dream" events or incidents that actually happened, either at the instant the dream occurred or the next day or next week, or at any time. Neither have I met a single individual who had such a dream or "foresaw" an unusual event. When we consider that out of thousands and thousands of dreams some one may have noticed such an incident, we must conclude that it was simply a coincidence, as where during a thunderstorm at night a relative or a friend exposed to the storm "is seen," either struck by lightning or being near the place where it did strike.

Now it would seem quite natural for one when awakened by the peal of thunder to think of his relative, and the sudden thought may be mistaken for a dream. Even if it were a real dream and "came true" it must still be regarded as a coincidence, as one instance out of thousands of dreams the rest of which did not come true. We hear of the particular one, and as just remarked, at second hand, or even a number of removes from the original source, to the neglect of all dreams that did not come true. At times we see a mention in the newspapers of dreams that "came true."

A second class is composed of those who pay no attention whatever to dreams, and also those whom one can not interest in the subject at all, who may even express disgust at the very idea of giving a dream a second thought. This class is as unsatisfactory to the student as the other.

Those who do give some attention to dreams and may be made to take additional interest when their attention is called to the subject form a third class—the class I have in mind in this paper. They are comparatively few—but, as in other things, to the few we owe our increase in knowledge.

Out of the long list of factors and conditions enumerated in this paper only a few, perhaps only one or two, may play an important role in the life of any one person; to him, however, they may be essential. As an example, we have the man who requires the quiet of the country, or on the other hand, the man who requires the stimulation of city life.

In asking for data one can put the question in several ways: In the case of those who have occasional periods when the mind is very active, we can ask, "Under what conditions does this occur?" "What causes the mind to become thus active?" While in those whose minds are nearly always active, but where there are occasional intervals of inactivity, when a man says, "I can't think," we may ask, "Why not?"

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As an addendum may be mentioned several other factors that stimulate the mind and bring on thoughts.

Trying it on the Audience—"for further inspiration." I recall how Dr. Jordan used to do this before his classes in Evolution, as he himself told us. I have often wondered how much inspiration he got from a dull class.

An Assigned Task, as a factor, as where a member of the Academy sends in his title, and as the time for the meeting approaches gradually

"gets busy," knowing that his paper must be ready at a certain time—for instance, myself during the last few days.

Finally may be mentioned the Annual Academy Meetings as a source of stimulation and of inspiration, especially to those of us who live in isolation. This is a factor in thought stimulation not to be undervalued.

# Hygiene of Indoor Swimming Pools, with Suggestions for Practical Disinfection.

By Severance Burrage.

The "Ole Swimmin' Hole" of our boyhood days is doomed. The favorite spot in pond or stream to which we used to go after school for a good swim and play, with no thought for the microbe in the water nor the bathing suit for our bodies, is, for the boy of today almost unknown, and for the boy of the future will be but an unrealizable dream. With the advance of civilization these swimming holes are being replaced by public bath-houses, and to these, or to gymnasiums that are provided with swimming tanks, the boys must go for their swim. The streams and ponds have become polluted to such an extent that it is dangerous for the boys to bathe therein. This is the result of the increase in population, coupled with the great carelessness of individuals and communities in the disposal of wastes. This replacement of the natural swimming pool by the indoor swimming pool may carry with it new unhygienic conditions, and it is a discussion of these conditions and their elimination that forms the purpose of this paper.

## CONSTRUCTION OF INDOOR SWIMMING POOLS.

One of the first requirements in the sanitary construction of the indoor swimming pool is that it must be so constructed that it may be easily cleaned. To this end the surface of the lining material of the pool should be very smooth, such a surface as is provided by glazed tiles so laid as to avoid all cracks and crevices. At the angles formed by the meeting of the sides and floor of the pool, curved tiling should be used, which would give the same result in the border of the pool flooring as is obtained in the angleless baseboard in up-to-date hospitals and operating rooms. The almost universal deposit of a slimy sediment in these pools, even when the water is comparatively clear, makes it necessary to provide for an easy and complete cleaning. A concrete or cement lining, made as smooth as it is possible to make it, furnishes a surface that is difficult to keep clean.

Fig. 1. Swimming Pool, Memorial Gymnasium, Purdue University.

A swimming pool lined with the glazed tile referred to above is shown in Fig. 1, Purdue University Memorial Gymnasium, 1909.

In addition to the outlets for the water in the bottom of the pool, it is advisable to have, at the overflow point, a sufficient number of outlets, or a trough extending all around the pool, so that when a scum or dirt collects on the surface of the water, the upper layers may be drawn off without necessarily emptying the whole pool.

Fig. 2. Men's Swimming Bath, Leeds, England. (Lighted by sky-light only.) By courtesy of "Modern Sanitation."

The floor of the pool room should be so drained that water dripping from bathers who have come out of the pool can not collect in puddles, and, furthermore, such water should drain, not back into the pool, but into the overflow waste pipes.

### The Water Supply.

The water supplied to the swimming pool must be pure, and every possible means used to keep it so during and after its use by the bathers. The nearest approach to an ideal water supply for an indoor swimming pool would be the provision for a pure water to start with, and a continuous change of water, during the use of the pool, the rate of this change being governed by the number of bathers in the pool. In most cases this is out of the question on account of the expense.

The water of these pools is not exposed to the many purifying factors that affect out-door waters. The pool is usually located in the basement or in buildings the interior of which the direct rays of the sun seldom reach. Thus one of the most important factors in the purification of natural waters is removed. It is true that the water does get some

aeration while the bathers are stirring it up, but because of the constant contamination at such times, this aeration cannot be counted upon as very much of a purifying factor. During the times when the pool is not being used, when the water is stagnant, no purification is taking place. On the contrary, bacteriological tests have shown that there is an increase in the bacterial content, particularly if the water has been warmed up to a temperature of 75 degrees Fahr. or over. There is considerable sedimentation during such times, but if this sediment remains in the bottom of the pool to be stirred up when the bathers next use the water, this cannot be looked upon as purification.

The cold plunge at the Fleischmann baths, New York City[1] has "enormous windows of plate glass facing south and the medicine of the sun and the glory of the sky." (Fig. 6.) Comparing this elegant sunny pool room with the condition in our average basement swimming pools.

Fig. 3. Women's Swimming Baths, Leeds, England. (Direct sunlight rarely reaches water.) By courtesy of "Modern Sanitation."

it makes the latter look dark and gloomy. The pool room at the Purdue gymnasium is on the south side of the building, and the windows are large for a basement room, and yet even this does not get the necessary sunlight for purposes of purification of the water.

At the swimming baths at Leeds, England (Cookridge street), the skylight is used for lighting the rooms, but even here the effect is none too brilliant. (Figs. 3 and 4.)[2]

[1] Lucy Cleveland, Modern Sanitation, Jan., 1908.
[2] Henry Gray, Modern Sanitation, Oct., 1909.

## Pollution of Water by Bathers.

A bacteriological study of the water used by a bather at the Victoria Baths at Bonn,[1] shows well the character and amount of pollution that may take place in public baths. The test was made on a stoker (Heizer), who was made to wash in a tub for three minutes, using no soap. Before the test, the bath water contained 24 bacteria in a cubic centimeter, and no *Bacillus coli*. After the three minute washing, the bath water contained 1,900 bacteria and 40 *Bacillus coli* in each cubic centimeter.

Bacteriological tests made by the writer on the water of the swimming pool in the new memorial gymnasium at Purdue University demonstrated the presence of 930 bacteria per cubic centimeter in the water of the pool before being used by the bathers. After use by about thirty bathers, all of whom were supposed to have taken a soap shower before entering the pool, the bacterial content was 109,200 per cubic centimeter. Tests were made for *Bacillus coli*, and the results were consistently positive after the pool had been used. The water immediately after cleaning the pool and refilling gave consistently negative results for *Bacillus coli*.

The available literature gave almost no data as to bacteriological analyses of swimming pool waters.[2]

### DISEASE DANGERS IN SWIMMING POOLS.

There are great chances for the dissemination of germ diseases through indoor swimming pools. The results of the bacteriological tests given in the preceding paragraphs, which showed the constant presence of the *Bacillus coli* in the water used by bathers, demonstrates the possibility of intestinal diseases, particularly typhoid fever. While bathers do not swallow the water intentionally, it is next to impossible to avoid getting some water into the nose and mouth, which would ultimately reach the intestinal tract. One does not have to be sick or to have any symptoms of typhoid fever to disseminate the germs of that disease. This is well shown in the notorious case of "Typhoid Mary" in New York.[3]

Diseases of the respiratory tract have an unusual chance to be spread in the swimming pool. The bather with incipient tuberculosis, pneumonia

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[1] Zur Hygiene der Hallenschwimmbade. Dr. Selter. Aus dem Hygienischen Inst. der Univ. Bonn. Rundschau, Dec. 1, 1908.

[2] Hesse, Dresden. Zeitschrift f. Hyg. Bd. 25. Eden, Berlin. Arch. f. Hyg. Bd. 19. Koslik, Gratz. Diese Zeitschr. 1898, S. 361.

[3] Whipple. Typhoid Fever.

or tonsillitis, with his sputtering, coughing, snorting and spitting, would undoubtedly infect the water with the specific germs of those diseases. Ordinary colds and sore throats following the plunge bath are frequently laid to the effects of the bath, while in most cases such results are undoubtedly due to germ infection. One of the factors which lead the writer to take up this subject was an epidemic of colds among the users of the Purdue swimming pool this fall.

Venereal diseases could be transmitted through the agency of the swimming pool. One case of gonorrhoea could infect many eyes in a crowded swimming pool.

It is practically impossible to compel the bathers to submit to a complete medical inspection and physical examination before they are allowed to enter the pool, and yet from many points of view this would be a most desirable thing.

The least that can be done for the protection of the bathers is to insist that certain rules be strictly adhered to. For example, such rules as the following are posted prominently in the Purdue gymnasium:

TAKE A SOAP SHOWER BEFORE ENTERING POOL.

All gymnasium privileges will be denied persons affected by any contagious or communicable disease.

All persons MUST take a soap shower before entering the pool.

All persons using the pool MUST wear bathing suits or trunks.

Of course facilities must be provided for the required showers, and each person should provide his own towel and soap.

In the Central Baths, Bradford, England, special arrangements are provided for washing the feet,[1] a most desirable thing as a prerequisite to the use of the pool. (See Fig. 7.)

### PRACTICAL PURIFICATION OF WATER IN SWIMMING POOLS.

The amount and character of the pollution in swimming pool waters point very clearly to the need of some practical process of purification. In most cases it is too expensive to have a continuous change of water, and

[1] Centralized Public Baths. Bertha H. Smith, Modern Sanitation. November, 1909.

ıme too expensive to change the water once or twice a week. At the ral Baths, Bradford, England, the water is filtered. The expense of ping the water and caring for the filter does not make the filtration ess a particularly economical one.

It occurred to the writer that some chemical, as copper sulphate or ·ide of lime, both of which are being used extensively in the purifica- of sewage and sewage polluted waters, might be used in the treatment vimming pool waters with but small expense. Inquiries in many di- ons and a careful search in available literature resulted in but scant ·mation. A single reference[1] reported the use of a chemical, an "elec- tic fluid," by the medical officer of health of the metropolitan borough

Fig. 5. Plunge, East 23d St. Public Bath, New York City. (A fairly well lighted indoor pool.) By courtesy of "Modern Sanitation."

oplar, Mr. F. W. Alexander. This fluid is obtained by the electrolysis solution containing magnesium chloride, the result being a solution agnesium hypochlorite. Treatment of water in swimming baths by luid was thought to be simple, economical and efficient, bacteriological on water so treated giving sterile results.

efore finding this reference the writer had conducted a series of n the water of the swimming pool at the Purdue gymnasium, using e of lime.

nmercial chloride of lime (bleaching powder) is usually manufac- y passing dry chlorine gas over freshly slaked lime, the chlorine

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ntific American Suppl. No. 1765, Oct. 30, 1909.

being obtained by the electrolysis of salt. This chloride of lime is composed largely of calcium hypochlorite. When added to water this hypochlorite dissolves, leaving a residue of calcium hydrate and calcium carbonate. Both of these substances are entirely harmless factors in a bath water. The oxidizing power of the commercial chloride of lime is represented by about 35 per cent of available chlorine. It is nascent oxygen that is the purifying factor, not the chlorine.

The capacity of the Purdue swimming pool is 85,000 gallons, and 680 grams of the chloride of lime were used at each dose. This would be about the equivalent of 20 pounds to the million gallons. Before starting the experiment with the chemical, bacteriological analyses were made of the water for a week, the pool being emptied twice. No attempt was made to keep track of the number of bathers in the pool.

The following table shows the results of the analyses for the week before using the chemical dosage, compared with the results of the analyses for the week while the dosage was going on. During the latter week, that is, while the tank was being dosed with the chemical, the water was not changed at all.

The method of applying the chemical was to sprinkle it on the surface of the water in the pool. This was easily done with one trip around the edge, throwing the powder as one walked. The time occupied in this process was less than two minutes.

| *Date.* | *No. of Bacteria per c. c.* | *B. Coli.* |
|---|---|---|
| Monday, November 1, pool just filled | 560 | None |
| Evening, after use | 6,160 | Present |
| Tuesday a. m., November 2 | 20,650 | Present |
| Evening, after use | 37,600 | Present |
| Wednesday a. m., November 3 | 27,800 | Present |
| Evening, after use | 60,500 | Present |
| Tank emptied. | | |
| Thursday a. m., just after filling | 930 | None |
| Evening, after use | 8,500 | Present |
| Friday a. m., temperature of water 85 Fahr | 109,200 | Present |
| Evening, after use | 106,400 | Present |
| Saturday a. m., November 6 | 118,000 | Present |
| Evening, after use | 140,000 | Present |

| | | |
|---|---|---|
| Monday, November 15, pool freshly filled........ .... | 780 | None |
| Evening, after use.............................. | 23,100 | Present |
| Pool dosed with 680 grams chloride lime. | | |
| Tuesday, November 16, a. m...................... | 26 | None |
| Evening, after use.............................. | 12,000 | Present |
| Pool dosed with chloride of lime. | | |
| Wednesday a. m., November 17.................... | 14 | None |
| Evening, after use (no sample). | | |
| Pool dosed with chloride of lime. | | |
| Thursday a. m., November 18, water had not been changed as was usually done............... | 9 | None |
| Evening, after use (no sample). | | |
| Pool not dosed. | | |
| Friday a. m., November 19........................ | 11,200 | Present |
| Evening, after use.............................. | 20,500 | Present |
| Dosed with chloride of lime. | | |
| Saturday, November 20........................... | 18 | None |
| Evening (no sample). | | |

A study of the results shown on this table indicates that the effect of the chloride of lime treatment is almost complete sterilization. The samples of water taken the morning after the water had been dosed in no case showed more than 26 bacteria per cubic centimeter. And what I believe to be a very important factor is that the general average of the bacteria is lower, much lower, than during the week when the chemical was not used. The effect of stopping the dosage is prettily shown in the Friday morning sample, November 19. The pool is used by the "coeds" and faculty ladies on Thursday evenings, and it was inconvenient for the writer to arrange to have the sample collected. No arrangement was made to have the chemical applied.

## SUMMARY AND CONCLUSIONS.

There are certain dangers to health in the indoor swimming pools. The construction of the pools, the enforcement or neglect of rules governing those who use the pools, the proper attention to the water supply, as to its purity before use by the bathers and after use, all have a direct bearing on the extent of these dangers.

On account of the expense it is practically impossible to provide for a continuous change of the water. The filtration of the pool water after use also involves some trouble and expense. The use of certain disin-

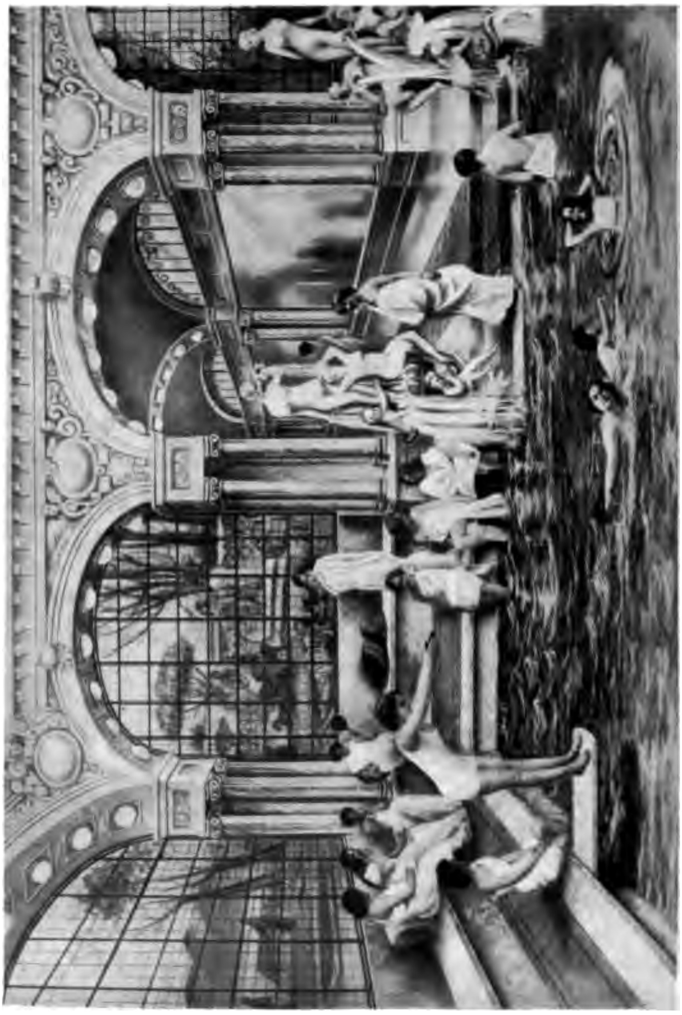

Fig. 8. Plunge, Fleischmann Baths, New York City. Women's Hour. (Showing unusual lighting for an indoor pool.) By courtesy of "Modern Sanitation."

fectants would seem to be more simple and economical. The writer would criticise the liquid or fluid chemicals as being harder to apply to the pool

water. They would have to be thoroughly stirred into the water. The substance used by the writer, chloride of lime, is sprinkled on the surface of the water, and it to a great extent distributes itself by sinking through the water. The results of the bacteriological tests certainly indicate that the substance has a very great purifying power.

Fig. 7. Facilities for foot-bath before entering plunge. Bradford, England. By courtesy of "Modern Sanitation."

The indoor swimming pool is a valuable hygienic factor in our public baths and gymnasiums. It makes the bath attractive to many who would otherwise look upon bathing as a bore. Anything which will tend to make the boys and girls, youths and maidens, men and women bathe more frequently is desirable. But the swimming pool has its dangers, and most of these depend not upon the users of the pools alone, but much more on the construction and management of them. Therefore we must look to the builders and directors of our baths and gymnasiums for the satisfactory hygiene and sanitation of indoor swimming pools.

# The Problem of Sewage Purification in Indiana.

By R. L. Sackett.

## CONDITIONS.

As the population of a city increases, the difficulties of obtaining a ıfficient water supply which is free from contamination by sewage be- ›mes more and more difficult. It is now a well established fact that ›wage-contaminated waters are to a considerable extent the cause of ımmer complaint and other bowel troubles, besides the more dangerous sease, typhoid fever. The extensive death rate among children is in ›me measure chargeable to impure water.

There are very few large cities that are able to obtain a ground water ' satisfactory quality and quantity. We are therefore driven to the use of ırface water.

## OBJECT OF SEWAGE PURIFICATION.

Large volumes of sewage are discharged into the White, the Wabash ıd Ohio rivers and their branches, also into Lake Michigan, by the cities tuated near them. In order to maintain a stream in a condition ap- ·oaching normal purity, methods for the purification of sewage are ap- ied, so that the resulting effluent discharged into a stream is purer. This ırification is obtained by some method of oxidation which will remove ıe putrefactive material or highly organized food on which pathogenic ıcteria live.

Sewage purification is a relative matter, and absolute purity of the fluent is practically impossible and generally is unnecessary. The prob- ›m, then, is to adapt available means to the conditions in order to eco- omically defend the people against water-born diseases.

Dilution may be considered a process of purification, and therefore he larger the volume of pure water available in a stream the lower the ercentage of purification required, for wherever there is running water ɔt already contaminated, oxygen is present and some purification takes ace; vegetation and sedimentation also assist.

The old theory that a stream would purify itself in a flow of ten miles as a dangerous one, because it depended distinctly on conditions.

In many instances no doubt typhoid has been carried thirty miles by a river, and then has caused a serious epidemic.

### PROCESS OF PURIFICATION.

While a certain amount of purification takes place in a septic tank, its office is rather that of changing the organic matter from the condition of suspension to one of solution. Hence it is now more frequently called a hydrolytic tank. It is, however, important in that it makes the succeeding processes of nitrification easier and permits of much more rapid treatment than would otherwise be possible.

The second step is one of several types of filtration. First, we might place the slow sand filter, which was usually some 3 or 4 feet deep; over the surface sewage flowed either continuously or intermittently, the latter being the more efficient method.

A second form was the contact filter, which was a tight tank filled with broken stone, coal or hard clinker. This tank was filled with sewage from the bottom, and after a time was emptied automatically.

The third and most successful type of filter is formed of stone, about one-half inch in diameter. Over the surface sewage is sprayed or sprinkled periodically by automatic syphons.

After filtration there is still left some organic matter, but, if the process is successful, it does not cause putrification. It is quite probable that some bacteria pass through the filter and thus gain access to the stream. Hence it has been proposed that where a high degree of purification is necessary the effluent from the filters should be sterilized.

### PURIFICATION PLANTS IN INDIANA.

Two or three tanks were installed in Indiana some ten years ago, and a set of four small sand filters was at one time (about 1900) in operation at Indiana Harbor, but has since been abandoned.

The oldest plant still in operation is at the Eastern Indiana Hospital for the Insane near Richmond. It consists of a concrete tank and intermittent sand filters. It treats the sewage of about 1,000 people and leaves the stream into which the effluent flows in a very satisfactory condition. It was built in 1901 at an expense of $9,000. The cost of operation has been negligible.

The second plant of any size was built at the Southern Hospital near Evansville. It was a chemical precipitation plant using lime or soda ash. After precipitation in large concrete tanks the sludge was pumped to a press; the resulting cake of organic matter was dumped into a cistern made for the purpose. The cost of the plant was originally $18,000, and the cost of operation about $1,200 per year.

It was replaced in 1905 by a three-step process which included tanks, stone filters and finally intermittent sand filters.

The conditions here required a high degree of purification. The population is approximately 1,000, and the cost of operation is probably less than $200 per year. The cost of reconstructing the plant was $10,000.

In 1908 the city of Bloomington constructed a system of sanitary sewers and installed a purification plant consisting of a central concrete tank and two series of stone filters, the latter being sprinkling filters.

Angola, a city of about three thousand population, is now constructing a system of sewers and a sewage purification plant consisting of sedimentation tanks, stone filters for the first treatment and sand filters for the final. The city will build a second plant next year. The cost of the two plants will be about $20,000. The cost of operation of these small municipal plants will be watched with interest, as it will determine in some measure the details of future designs.

The city of Laporte, with a population of 12,000 and rapidly growing, is completing plans for a system of sewers and is providing for sewage purification.

The city of Shelbyville is also constructing a system of sanitary sewers, and the entire town looks forward to sewage purification at some time.

There is no question but that the educational propaganda which the State Board of Health has been pursuing is bearing fruit. The state institutions themselves are with a few exceptions well provided with a good water supply and sewage purification plants where they would otherwise prove a danger to neighboring communities.

There can be no doubt but that this movement toward pure water will have a measurable effect upon the morbidity and mortality of the State.

Purdue University.
Lafayette, Ind.

# That Erroneous Hiawatha.

By Albert B. Reagan.

Hiawatha, hero of Longfellow's poem of the same name, is not recognized as a hero god by the Chippewa Indians. Neither the name nor the person designated occurs in the mythology of these people. Their god is Menibusha, and the only word approaching Hiawatha is Ket'-che-wah'-sah, which means "afar off." Through the kindness of the Indian missionary and court-agency interpreter here, Rev. Frank H. Pequette, who is himself a Chippewa and has lived and preached in various parts of the Chippewa country, I quote his own summing up of this subject:

"When a white man asks an American who is the greatest man of his country he answers, 'George Washington.' But I am here to declare that Hiawatha is not the hero of my race. This personage is unknown to the Chippewa Indian.

"The Indian lad sitting in the forest with his bow and arrow, observing the trees and the sky and the sand and the water of the Great Lakes and the animals and the fishes, asks himself, 'Who made these?' He cannot answer the question himself, so he asks the old medicine man of his tribe. 'Menibusha,' answers the sage. 'Menibusha made the earth, sky, the sun, moon and stars, and the wild things and the fishes, and he made you also, my son.' So says the medicine man of the tribe. Menibusha also made the land, the island-continental surface on which we now live. He is the first brother of all mankind and now lives in the East.

"All the Indians before they became Christians (that is, all Chippewas) supposed that Menibusha was the Supreme, the greatest man and god of his nation. And when the first white man asked the Indian the question who was their greatest personage the Indian replied, 'Menibusha.' 'Where does he live?' of course asked the white man. 'Ket'-che-wah'-sah,' replied the Indian—meaning (that he was) afar off. The white man's ears were not tuned to the Indian sounds used in pronunciation and he caught it Hiawatha, which did not mean god, but 'afar off'; and one great white fellow, Longfellow by name, wrote our legends with this unknown Hiawatha. But this Hiawatha is not known to us Indians."

# Medicinal Value of Eupatorium Perfoliatum.

By A. J. Bigney.

Eupatorium perfoliatum, commonly known as thoroughwort, or boneset, is a well-known plant, yet its real medicinal value is not as well known as it should be. This plant varies from two to four feet in height, blossoming in August and September, and is abundant in flat and swampy lands. It seldom grows in hilly sections. Nature seems to have made provision for the curing of the diseases prevalent in certain regions. In swampy countries chills, malarial, intermittent, typhoid and other fevers are common. Since boneset occurs in these localities and is particularly valuable for curing such diseases it seems to substantiate the above statement.

The blossoms, small branches and leaves are the parts generally used. It has four medicinal properties—an emetic, a tonic, a light laxative and a diaphoretic. As a diaphoretic it should be taken hot just before retiring. This is specially helpful for colds and fevers. For restoring the powers of the stomach it is better to take boneset cold.

For the diseases already mentioned boneset has been known and used as a home remedy for a long time. In the so-called la grippe it has not been used very extensively so far as I can learn. Some prominent physicians say it is almost a specific for it.

My experience in its use dates from the first appearance of la grippe in this community, about 1889. As soon as the symptoms begin a teacupful of the infusion of the boneset is taken just before retiring. This produces some perspiration, strengthens the nerves, regulates the digestive organs, thus giving the body an opportunity to increase the building up of the system, and in this way the resisting power is sufficient to overcome the disease. Occasionally the next day some of the cold infusion may be taken, always before meals, for, after eating, the emetic power may predominate. The next night the hot solution should be taken. Usually this kind of treatment will cure the disease without going to bed at all. This treatment should be taken early in the development of the disease in order to get the best results.

The first time of taking it, it should not be very strong until a person finds out its action on his stomach, for the emetic influence is exerted much stronger in some persons than in others. If one can retain it, it matters but little about the strength of it. It is made as ordinary tea.

I have thoroughly tested it in my own case when la grippe has been making its invasion, and as a result I have never yet had a regular siege of the disease. My own family has tried it time and again with splendid results. Some people cannot take it at all because of its emetic effect. I have given my neighbors the benefit of my experience. While its results are always good, yet in some persons the results will not be as marked as in others.

The students of Moores Hill College have been very willing to respond to my desire to have them test it. Students have come into the class-room with the symptoms strongly developed, and on being advised to take this remedy have actually taken it that night. They would report that the results were even better than they could have expected in so short a time. They would not even have to stop work. Scores of reports could be given, but I do not think it necessary. The best way will be to test it for yourself. It can be secured from your druggist if it does not grow in your locality. An extract of boneset is made, but I have had no experience with it.

I am pretty thoroughly convinced that nearly every case of la grippe can be cured by this remedy if taken early in the development of the disease.

Moores Hill College,
Moores Hill, Ind.

# Refractive Index as a Measure of Dry Substance in Saccharine Products.*

By A. Hugh Bryan.

Dry substance determinations are the most difficult determinations a a chemist has to make, and again one of the most important. In sugar materials, containing many organic substances and also inorganic salts, various reactions and changes are going on when the sample is heated in the course of making a dry substance determination. Varying degrees of heat also tend to decompose these substances. Also, the length of time of heating is a very important factor. The accepted method for sugar compounds, where accurate results are desired, is the loss of weight at 70° C. when heated in vacuum. It has been found at that temperature that levulose shows little, if any, decomposition. Sugar chemists of Germany modify that procedure by drying at 65° to 70° C. in the air until all visible water is gone, and then heat for from 2 to 4 hours at 105° C. in vacuum, it being claimed that by first drying and then heating to 105° in vacuum, no sugar is decomposed. It is a fact, however, that if one makes two determinations of moisture on the same sample at different times, it is more than likely that the results will not check. Differences of as high as 0.5% have been noted, especially where the substance under examination is high in reducing sugars. It can hardly be expected to obtain a method for determining moisture accurately without a direct determination of this by drying. Such a procedure takes time, and at its best, so far, gives only approximate results.

The refractometer was first tried in sugar work by Strohmer (Zeit Ruben Zuckerind., Vol. 21, p. 256) in 1884 and again in 1886 by Muller (Ibid. Vol. 37, p. 91). They showing that the index depended on the concentration of solution. The latter investigator gave a table for estimating the dry substance of beet juices from the refractive index. Again in 1901, Stolle published a table for the above. All of these used the old forms of instruments. Tolman and Smith,[1] using the heatable prism instrument, such as is used today, and pictured later in this paper, found

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[1] Jour. Amer. Chem. Soc. (1906), 28, 1476.

that for equal concentrations, all sugars have about the same index of refraction. Main[1] published tables of water content from refractive index in 1907, and called attention to the accuracy of this method, as compared with the true dry substance. Since that time the literature has been full of articles on this method of determining the dry substance.

All authors, with but few exceptions, claim much for this method as a quick one and yielding comparable results. They all agree that the results so obtained are nearer the true dry substance than by obtaining the dry substance from the specific gravity. The substances dissolved along with the sugar seemingly have a closer refractive index to sugar than specific gravity.

Working on syrups of various origins, I obtained the following average figures.[2] The method for true dry substance was loss of weight in vacuum at 70° C. The table of Prinsen Geerligs, and also his corrections for temperature were used. These are given later in this paper.

IN CASE OF MAPLE SYRUP.

Thirteen samples were examined. In only one case was the refractometer dry substance higher than the true, and in all others the true dry substance was higher. This difference ranged from 0.20% to 1.34% with an average of 0.50%.

WITH CANE SYRUP.

Ten samples were examined. In three cases the refractometer dry substance was higher than the true by 0.16%, 0.34%, 0.62%. The other cases range from 0.24% to 0.93%, or an average difference on the whole of 0.29%.

HONEYS.

Twenty-four samples were examined. In 2 cases the refractometer dry substance was higher than the true by 0.21% and 0.91%. In all the rest it was lower by from 1.15% to 2.52%, with an average of 1.45%. This is the greatest difference noted. One of three causes or all may account for this large difference. (1) The actual dry substance may not be right, viz., this product may not give up all of its water at 70° in vacuum, or, (2) the dextrin of the honey may change the refractive index of the

[1]Inter. Sugar J. (1907), 9, 481.

[2]NOTE. See Jour. Amer. Chem. Soc. (1908), 30, 1443, for a previous paper on this subject by the author.

whole, or, (3) the values given in the table for dry substance from refractive index may not be right.

### COMMERCIAL GLUCOSE.

The two samples examined show the refractive index dry substance higher by 0.27% than the real dry substance. The closeness of these readings would tend to disprove the second cause for honey.

### CANE MOLASSES.

Seventeen samples were examined. In 3 cases the refractometer dry substance was higher than the true by 0.16%, 0.39%, and 0.59%. In all the rest it was lower by from 0.38% to 1.53%. The average difference was 0.79%.

### BEET MOLASSES.

Fifteen samples were examined. In all cases the true dry substance was higher than the refractometer. The difference varied from 0.38% to 1.83%, with an average of 1.08%. When the original substance was diluted one-half with water, and a reading made on this, the dry substance obtained was doubled. The results showed 5 cases where the refractive index dry substance was higher than the true by from 0.25% to 0.53%. In all other cases, the true was the highest by from 0.39% to 1.62%, with an average of 0.36%. It is seen then by dilution, the average difference between the true dry substance and refractometer has dropped from 1.08% to 0.36%. The results then are nearer the true dry substance. This comes about by being able to get a clearer field and thereby a closer reading.

However, later work has shown that this dilution with water, even though it has brought the dry substance by refractometer nearer the true dry substance, introduces a serious error. When water is added to molasses there is a contraction in volume.

This contraction has been taken into account in the construction of specific gravity and refractometer table for pure sugars so that solutions of the latter, whether mixed with water or a sugar syrup, will give the correct percentage of solids either by specific gravity or refractive index.

The impurities, however, which accompany sugars in solution in molasses, have not only a different specific gravity than sugar, but also a

different contraction co-efficient, so that the solution diluted with water shows a different specific gravity or refractive index than that calculated from tables for pure sugars.

To reduce these variations of contraction to the minimum, a concentrated pure sugar solution is used as a dilutant. Results obtained with some cane molasses samples show the error that is introduced by the water dilution and also the effect of the sugar dilution.

| Sample No. | Undiluted Molasses. | Diluted Half With — | |
|---|---|---|---|
| | | Water. | Sugar Sol. |
| 1 | 80.57 | 83.24 | 80.91 |
| 2 | 72.32 | 72.94 | 72.21 |
| 3 | 77.92 | 78.44 | 77.91 |
| 4 | 73.92 | 75.34 | 73.81 |
| 5 | 82.05 | 84.44 | 82.41 |

In the undiluted form all of these can be easily read. The half dilution with water is anywhere from .62% to 2.7% higher than undiluted while the half dilution with sugar solution varies from 0.0 to 0.3%.

Tischtschenko (Z. des Vereins Deut. Zuckerind., Feb. 1909, 103), calls attention to this possible error in the determination and recommends the use of a pure sugar solution. Von Lippman corroborates the results (Deut. Zuckerind., 34, 1909, 401). It therefore behooves us to use sugar solution in diluting our dark colored solution in preference to water. The formula for calculating the dry substance when using a concentrated sugar solution as a dilutant is:

$$X = \frac{(A + B)C - BD}{A}$$

in which X % dry substance of the original sample, (A) the grams of the original substance mixed with (B) the grams of concentrated pure sugar solution, (C) the % dry substance of the mixture obtained from its refractive index, and D = the % dry substance of the pure sugar solution obtained from its refractive index. The method of procedure is simply the preparation of a concentrated granulated sugar solution and mixing in a small beaker a weighed quantity of this with a weighed quantity of the original solution or sample, and taking refractive index of the mixture.

Summarizing the average results, we find that the refractometer dry substance is higher than the true.

| | Per Cent. |
|---|---|
| The difference in case of maple syrup ................ | 0.50 |
| The difference in case of cane syrup .................. | 0.29 |
| The difference in case of honeys ...................... | 1.45 |
| The difference in case of glucose ..................... | 0.27 |
| The difference in case of cane molasses ............... | 0.79 |
| The difference in case of beet molasses ............... | 1.08 |
| The difference in case of beet molasses (half) ........ | 0.36 |

With the exception of the honeys and possibly cane molasses, also beet molasses undiluted, the differences are well within the error of determination of water by actual drying. By half dilution, the beet molasses is brought within the limits, and where dilution with sugar solution tried this difference would be cut down considerably. Cane molasses, showing 0.79%, might be considered within the limits, as a true moisture content on this material is a difficult task. Honeys are, then, the only ones whose difference is large, but it is hoped that with the work now being carried on, the reason for this difference will be obtained and a method for procedure be established for this grade of substance. However, there is one thing to be said in regard to the refractometer, that it is possible to obtain duplicate results that are identical, and different investigators should obtain identical results, which is a condition that does not exist with the other methods for dry substance determination in use now. The refractometer method has the advantage of being quick and not losing accuracy by speed, and then only small portions are necessary for a determination.

The method of making a dry substance determination is substantially this: The instrument (Fig. 1) is placed so that the light falls on the mirror (R) and this is turned on its axis to reflect the light up through the prism (B) and (A). The source of light can be daylight, but a better one is a 32 or higher candle power lamp. The tubular (D) is connected by rubber tubing to the source of water supply of constant temperature and the other tubular (E) has a rubber overflow connection. The thermometer is placed in its socket. The optical parts of the instrument are turned forward on the stand (a). By turning the catch (V) the prism B is swung open on (C) from prism (A) and a few drops of the solution to be examined is placed on the prism (A). Enough of the solution should be added so that on closing the prism (B) on (A) a part of the liquid is forced out. The optical parts are brought back into their original place.

The arm carrying the magnifying glass (L) should be down to the 1.3 end of the scale. Then by looking through the eyepiece (F), focusing the cross-hairs into plain view, the arm (L) is moved until a bright color appears in the lower half of the field. By turning the milled screw (M)


Fig. 1.

of the compensator the line of color is made more distinct; viz., there is sharpness of line dividing the light and the dark field. By moving the arm farther this line is brought up to a point where it coincides with the intersection of the cross-hairs. At this point, the index of refraction is

read on the scale (J). At the same time the temperature is read on the thermometer.

The instrument should be tested first with water and its accuracy established thereby: Ref. Ind. of water at 20° being 1.3330. The substance to be examined should be at about the same temperature at which the readings are to be made. Therefore waiting a few minutes after applying the liquid to the prism, it could be considered that this is at the same temperature.

Tables have been prepared for converting the refractometer readings to dry substance or per cent. of moisture. To some of these previous reference has been made. Hugh Main, in the International Sugar Journal of 1907, Vol. 9. page 481, gives a table covering this. The readings are to be made at 20° C. Geerligs has published a table also for dry substance from the refractive index. The temperature of the reading is 28° C. and he has also prepared a table for corrections for other temperatures than 28°. These are now given:

*Geerlig's Table for Dry Substance in Sugar-House Products by Abbé Refractometer, at 28° C.*

(Intern. Sugar J., *10*, 69-70.)

| Index. | Per Cent. Dry Substance. | Decimals. | |
|---|---|---|---|
| 1.3335 | 1 | 0.0001=0.05 | 0.0010=0.75 |
| 1.3349 | 2 | 0.0002=0.1 | 0.0011=0.8 |
| 1.3364 | 3 | 0.0003=0.2 | 0.0012=0.8 |
| 1.3379 | 4 | 0.0004=0.25 | 0.0013=0.85 |
| 1.3394 | 5 | 0.0005=0.3 | 0.0014=0.9 |
| 1.3409 | 6 | 0.0006=0.4 | 0.0015=1.0 |
| 1.3424 | 7 | 0.0007=0.5 | |
| 1.3439 | 8 | 0.0008=0.6 | |
| 1.3454 | 9 | 0.0009=0.7 | |
| 1.3469 | 10 | | |
| | | | |
| 1.3481 | 11 | 0.0001=0.05 | |
| 1.3500 | 12 | 0.0002=0.1 | |
| 1.3516 | 13 | 0.0003=0.2 | |
| 1.3530 | 14 | 0.0004=0.25 | |
| 1.3546 | 15 | 0.0005=0.3 | |
| 1.3562 | 16 | 0.0006=0.4 | |
| 1.3578 | 17 | 0.0007=0.45 | |
| 1.3594 | 18 | 0.0008=0.5 | |
| 1.3611 | 19 | 0.0009=0.6 | |
| 1.3627 | 20 | 0.0010=0.65 | |
| 1.3644 | 21 | 0.0011=0.7 | |
| 1.3661 | 22 | 0.0012=0.75 | |
| 1.3678 | 23 | 0.0013=0.8 | |
| 1.3695 | 24 | 0.0014=0.85 | |
| 1.3712 | 25 | 0.0015=0.9 | |
| 1.3729 | 26 | 0.0016=0.95 | |
| | | | |
| 1.3746 | 27 | 0.0001=0.05 | 0.0012=0.6 |
| 1.3764 | 28 | 0.0002=0.1 | 0.0013=0.65 |
| 1.3782 | 29 | 0.0003=0.15 | 0.0014=0.7 |
| 1.3800 | 30 | 0.0004=0.2 | 0.0015=0.75 |
| 1.3818 | 31 | 0.0005=0.25 | 0.0016=0.8 |
| 1.3836 | 32 | 0.0006=0.3 | 0.0017=0.85 |
| 1.3854 | 33 | 0.0007=0.35 | 0.0018=0.9 |
| 1.3872 | 34 | 0.0008=0.4 | 0.0019=0.95 |
| 1.3890 | 35 | 0.0009=0.45 | 0.0020=1.0 |
| 1.3909 | 36 | 0.0010=0.5 | 0.0021=1.0 |
| 1.3928 | 37 | 0.0011=0.55 | |
| 1.3947 | 38 | | |
| 1.3966 | 39 | | |
| 1.3984 | 40 | | |
| 1.4003 | 41 | | |
| | | | |
| 1.4023 | 42 | 0.0001=0.05 | 0.0012=0.6 |
| 1.4043 | 43 | 0.0002=0.1 | 0.0013=0.65 |
| 1.4063 | 44 | 0.0003=0.15 | 0.0014=0.7 |
| 1.4083 | 45 | 0.0004=0.2 | 0.0015=0.75 |

| Index. | Per Cent. Dry Substance. | Decimals. | |
|---|---|---|---|
| 1.4104 | 46 | 0.0005=0.25 | 0.0016=0.8 |
| 1.4124 | 47 | 0.0006=0.3 | 0.0017=0.85 |
| 1.4145 | 48 | 0.0007=0.35 | 0.0018=0.9 |
| 1.4166 | 49 | 0.0008=0.4 | 0.0019=0.95 |
| 1.4186 | 50 | 0.0009=0.45 | 0.0020=1.0 |
| 1.4207 | 51 | 0.0010=0.5 | 0.0021=1.0 |
| 1.4228 | 52 | 0.0011=0.55 | |
| 1.4249 | 53 | | |
| 1.4270 | 54 | | |
| | | | |
| 1.4292 | 55 | 0.0001=0.05 | 0.0013=0.55 |
| 1.4314 | 56 | 0.0002=0.1 | 0.0014=0.6 |
| 1.4337 | 57 | 0.0003=0.1 | 0.0015=0.65 |
| 1.4359 | 58 | 0.0004=0.15 | 0.0016=0.7 |
| 1.4382 | 59 | 0.0005=0.2 | 0.0017=0.75 |
| 1.4405 | 60 | 0.0006=0.25 | 0.0018=0.8 |
| 1.4428 | 61 | 0.0007=0.3 | 0.0019=0.85 |
| 1.4451 | 62 | 0.0008=0.35 | 0.0020=0.9 |
| 1.4474 | 63 | 0.0009=0.4 | 0.0021=0.9 |
| 1.4497 | 64 | 0.0010=0.45 | 0.0022=0.95 |
| 1.4520 | 65 | 0.0011=0.5 | 0.0023=1.0 |
| 1.4543 | 66 | 0.0012=0.5 | 0.0024=1.0 |
| 1.4567 | 67 | | |
| 1.4591 | 68 | | |
| 1.4615 | 69 | | |
| 1.4639 | 70 | | |
| 1.4663 | 71 | | |
| 1.4687 | 72 | | |
| | | | |
| 1.4711 | 73 | 0.0001=0.0 | 0.0015=0.55 |
| 1.4736 | 74 | 0.0002=0.05 | 0.0016=0.6 |
| 1.4761 | 75 | 0.0003=0.1 | 0.0017=0.65 |
| 1.4786 | 76 | 0.0004=0.15 | 0.0018=0.65 |
| 1.4811 | 77 | 0.0005=0.2 | 0.0019=0.7 |
| 1.4836 | 78 | 0.0006=0.2 | 0.0020=0.75 |
| 1.4862 | 79 | 0.0007=0.25 | 0.0021=0.8 |
| 1.4888 | 80 | 0.0008=0.3 | 0.0022=0.8 |
| 1.4914 | 81 | 0.0009=0.35 | 0.0023=0.85 |
| 1.4940 | 82 | 0.0010=0.35 | 0.0024=0.9 |
| 1.4966 | 83 | 0.0011=0.4 | 0.0025=0.9 |
| 1.4992 | 84 | 0.0012=0.45 | 0.0026=0.95 |
| 1.5019 | 85 | 0.0013=0.5 | 0.0027=1.0 |
| 1.5046 | 86 | 0.0014=0.5 | 0.0028=1.0 |
| 1.5073 | 87 | | |
| 1.5100 | 88 | | |
| 1.5127 | 89 | | |
| 1.5155 | 90 | | |

*Table of Corrections for the Temperature.*

| Temperature of the Prisms in °C. | Dry Substance. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 40 | 50 | 60 | 70 | 80 | 90 |
| | Subtract. | | | | | | | | | | | | |
| 20 | 0.53 | 0.54 | 0.55 | 0.56 | 0.57 | 0.58 | 0.60 | 0.62 | 0.64 | 0.62 | 0.61 | 0.60 | 0.58 |
| 21 | 0.46 | 0.47 | 0.48 | 0.49 | 0.50 | 0.51 | 0.52 | 0.54 | 0.56 | 0.54 | 0.53 | 0.52 | 0.50 |
| 22 | 0.40 | 0.41 | 0.42 | 0.42 | 0.43 | 0.44 | 0.45 | 0.47 | 0.48 | 0.47 | 0.46 | 0.45 | 0.44 |
| 23 | 0.33 | 0.33 | 0.34 | 0.35 | 0.36 | 0.37 | 0.38 | 0.39 | 0.40 | 0.39 | 0.38 | 0.38 | 0.38 |
| 24 | 0.26 | 0.26 | 0.27 | 0.28 | 0.28 | 0.29 | 0.30 | 0.31 | 0.32 | 0.31 | 0.31 | 0.30 | 0.30 |
| 25 | 0.20 | 0.20 | 0.21 | 0.21 | 0.22 | 0.22 | 0.23 | 0.23 | 0.24 | 0.23 | 0.23 | 0.23 | 0.22 |
| 26 | 0.12 | 0.12 | 0.13 | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.15 | 0.14 |
| 27 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.07 |
| | Add. | | | | | | | | | | | | |
| 29 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.07 |
| 30 | 0.12 | 0.12 | 0.13 | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.15 | 0.14 |
| 31 | 0.20 | 0.20 | 0.21 | 0.21 | 0.22 | 0.22 | 0.23 | 0.23 | 0.24 | 0.23 | 0.23 | 0.23 | 0.22 |
| 32 | 0.26 | 0.26 | 0.27 | 0.28 | 0.28 | 0.29 | 0.30 | 0.31 | 0.32 | 0.31 | 0.31 | 0.30 | 0.30 |
| 33 | 0.33 | 0.33 | 0.34 | 0.35 | 0.36 | 0.37 | 0.38 | 0.39 | 0.40 | 0.39 | 0.38 | 0.38 | 0.38 |
| 34 | 0.40 | 0.41 | 0.42 | 0.42 | 0.43 | 0.44 | 0.45 | 0.47 | 0.48 | 0.47 | 0.46 | 0.45 | 0.44 |
| 35 | 0.46 | 0.47 | 0.48 | 0.49 | 0.50 | 0.51 | 0.52 | 0.51 | 0.56 | 0.54 | 0.53 | 0.52 | 0.50 |

*Example:* Desired, the dry substance of a sample whose refractive index is 1.4589 taken at 26° temperature. The nearest index is 1.4567, which equals 67% then 1.4589 minus 1.4567 (the nearest value in the table lower than it) =.0022. In the decimal column opposite look for .0022 and one finds a value of 0.95. So the reading is 67.95 but at a temperature of 26° (from the table of corrections) .16 must be subtracted or the correct dry substance would be 67.79. In like manner the dry substance of a sample with a refractive index of 1.5021 at 28° C. would be 85.05, and one of 1.3802 at 28° would be 30.1, and one of 1.3655 at 33° C. would be 22.06.

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# Conductivity of Certain Salts in Ethyl Amine.

By Edward G. Mahin.

The conductivities of silver nitrate, lithium chloride and ammonium chloride in ethyl amine were measured by Shinn,[1] who showed that the molecular conductivities change with dilution in an unexpected manner. In the case of silver nitrate the molecular conductivity decreases with dilution until V=75.15, this being the highest dilution used. The molecular conductivity of lithium chloride increases with dilution until V=0.867, then decreases until V=21.08, after which it apparently slightly increases. The molecular conductivity of ammonium chloride decreases with dilution until V=18.24, after which it increases. These facts would not seem remarkable were it not for the concluding words of the author's paper. After summarizing the results of his experimental work, he says:

"From the standpoint of the theory of electrolytic dissociation the electrical behavior of solutions in primary and secondary amines and in amides, so far as such solutions have been studied, is inexplicable. The facts that for one and the same solute the conductivities of solutions may not only be very large or very small, but may increase or decrease with dilution, or attain maximum or minimum values depending upon the specific nature of the solvent, suggest that the role of the solvent in the process of the transmission of an electric current through a solution is, in all probability, a very active rather than an indifferent one, and does not materially differ from that of the solute. In such event, the prevalent conception of 'molecular conductivity' becomes not only meaningless, but misleading."

In arriving at the conclusions here indicated it would seem that the author has overlooked certain facts which may not only serve to explain the apparent departure from the dilution laws, but which would make this departure seem inevitable. It has long been known that the aliphatic amines are strongly basic substances, forming simple salts analogous to the ammonium salts, as well as complex metallic salts which are analogous to those where hydrogen of the ammonium radicle is substituted by a metal. Indeed, this salt formation is to be expected since the ali-

[1] J. Phys. Ch., *11*, 537.

phatic primary amines are members of a series of mono-substituted ammonias, of which the basicity is greater than that of the mother substance.

Köhler[1] isolated a salt having the composition represented by the formula $C_2H_5NH_2.HgCl$. Müller[2] investigated double salts of ethyl amine with palladium, Jorgensen[3] those with platinum, Carson and Norton[4] those with uranium, Bailey[5] with vanadium, Bonnefoi[6] with lithium chloride, and Hoffman and Marburg[7] with mercuric chloride. In most cases more than one salt was produced by varying the proportions of ethyl amine and the simple salt used. Hoffman and Marburg isolated and studied the compounds $C_2H_5NH_2.HgCl_2$, $(C_2H_5NH_2)_2HgCl$, and $C_2H_5NH.HgCl$. Bonnefoi found that by leading the vapor of ethyl amine over dry lithium chloride various double salts were produced, the proportion of the constituents depending upon the temperature. The following compounds were formed under the conditions indicated:

| *Temp.* | *Formula.* | *Heat of Formation, Calories.* |
|---|---|---|
| 70° | $C_2H_5NH_2.LiCl$ | + 13834 |
| 58°–70° | $(C_2H_5NH_2)_2.LiCl$ | + 24817 |
| Ord. to 58° | $(C_2H_5NH_2)_3.LiCl$ | + 35387 |

It seems probable, in the light of these facts, that at still lower temperatures other compounds will be present, having a still higher ratio of ethyl amine to the original salt; this should be particularly true with regard to solutions in liquid, anhydrous ethyl amine. In other words, we are here dealing with an application of the mass law, where the temperature and mass of the reacting substances are to be considered in the attempt to solve the problem regarding the composition of the resulting compound. We should expect that any solution would contain several compounds of the constituents, having a certain average composition which would depend upon the temperature and degree of dilution.

Shinn[8] tested, in an approximate but not quantitative manner, the action of ethyl amine upon 14 salts, concerning which the following résumé is here given:

[1] Ber., *12*, 2323.
[2] Ann., *86*, 366.
[3] J. pr. Ch., (2) *33*, 517.
[4] Am. Ch. J., *10*, 220.
[5] J. Ch. Soc., *45*, 693.
[6] C. r., *129*, 1257.
[7] Ann., *305*, 191.
[8] Loc. cit.

$NH_4Cl$.... Very soluble with evolution of ammonia.
$LiCl$ ..... Soluble.
$FeCl_3$..... Slightly soluble.
$SnCl_2$..... Insoluble, unchanged.
$CoCl_2$ .... Reacts with evolution of heat, forming greenish yellow precipitate.
$PbBr_2$ .... Reacts, forming white precipitate which afterward redissolves.
$KI$ ...... Insoluble, unchanged.
$CdI_2$...... Reacts, forming white, insoluble precipitate.
$AgCN$ .... Slightly soluble.
$Hg(CN)_2$.. Slightly soluble.
$AgNO_3$ ... Soluble with evolution of much heat.
$NaNO_3$ ... Insoluble, unchanged.
$Pb(NO_3)_2$.. Reacts, forming white, insoluble precipitate.

It is thus seen that, in all cases where the salt dissolves appreciably, there is evidence of chemical action, either through the evolution of heat or the formation of a precipitate, or both. In the case of ammonium chloride the well known action of evolution of ammonia was observed. There is, therefore, every reason for expecting that complex salts will be formed in every case excepting the last, where no doubt ethyl amine hydrochloride is produced, as Shinn has pointed out. If this be true, the question still remains as to whether the reaction is complete as soon as the salt is all in solution, so that henceforth all physical properties will be those of a solution in ethyl amine of a definite double or complex salt, changing with dilution only with respect to the degree of ionization. With the investigations of Hofmann and Marburg and of Bonnefoi in mind, the answer to this question would certainly be negative. We should expect that the ratio of ethyl amine to simple salt combined with it would not only change with lowering of temperature, but that it would increase with decreasing concentration, because as dilution progresses the ratio of amine to salt in solution increases. If the conductivity of the complex salt is much less than that of the simple salt the change in molecular conductivity with change in concentration would be the resultant of two influences, i. e., change in ionization and change in complexity of the ions. The migration velocity of a complex cation containing one or more molecules of ethyl amine could not be very high, and it is not likely that such a compound would possess a very high degree of ionization. This fact would then result in a more or less gradual tendency toward falling off in the molecular conductivity with increasing dilution, since we are actually dealing not only with more complex compounds, whose ioniza-

tion is probably less than that of the simpler ones, but also with more complex ions, whose velocity is probably less than that of the simpler ones. If, however, the ionization resulting from dilution proceeds at a greater rate than does the change in complexity, increase in molecular conductivity would then be the rule. This actually happens for a certain range in the case of lithium chloride. then later the increasing complexity of the ions perhaps gains the ascendancy and molecular conductivity decreases with further dilution. The effect of dilution upon molecular conductivity will necessarily be somewhat complicated, if the preceding reasoning is correct, involving at least the following changes: (a) Increase in molecular complexity, through increase in the active mass of ethyl amine. (b) change (probably decrease) in *ionization constant* because of increasing complexity, (c) increase in ionization of any one form, since at any dilution a considerable number of different complexes are probably present, and (d) probable decrease in migration velocity on account of increasing complexity of the ions.

This would seem to be merely another special case of the influence of solvate formation upon conductivity. and such influences have long been known. The formation of hydrates, for example, has a very marked effect upon the conductivity and upon the lowering of freezing point and vapor pressure of aqueous solutions.

In the case of solutions of ammonium chloride in ethyl amine it is by no means certain that the entire amount of salt is converted at once into ethyl amine hydrochloride when brought into a solution of any concentration. We should certainly expect that equilibrium will result when a certain amount of ammonium chloride remains as such in the solution, this amount becoming smaller as dilution proceeds. The molecular conductivity will then depend upon (a) the ratio of ethyl amine hydrochloride to ammonium chloride, (b) the relative ionization constants of the two compounds and (c) the relative migration velocities of the two (or more) cations involved.

The theory of electrolytic dissociation has proven of so great value to physical chemistry and has piloted the way to so many valuable investigations that one cannot fail to realize its importance. This does not mean that its imperfections should be ignored or that there should be any cessation in the search for facts which will test it to the extreme. But so many supposed objections have been urged against it that, on closer

investigation, have been found to entirely conform to the theory or to require only minor modifications, that we hesitate to accept such a sweeping statement as that contained in Shinn's paper. The facts cited do not necessarily conflict with the theory—indeed, they would seem to point to the truth of the theory. What is needed is more experimental evidence covering these points.

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# [S]TUDY OF THE CHEMICAL COMPOSITION OF BUTTER FAT, [A]ND ITS RELATION TO THE COMPOSITION OF BUTTER.

BY O. F. HUNZIKER AND GEORGE SPITZER.

## [SUMM]ARY OF AUTHENTIC KNOWLEDGE OF THE COMPOSITION OF BUTTER FAT.

[Mi]lk fat or butter fat consists of triglycerides of fatty acids. The [a]cids of butter fat are monobasic and have the general formula [$C_nH_{2n+}$]$_1$ CO OH, except oleic acid, which is a non-saturated acid be[longs] to the acrylic series with the general formula $C_nH_{2n-1}$ CO OH. [Tr]iglycerides of butter fat do not exist as glycerides of one fatty acid, [but] a mixture of several acid radicals combined with glycerin. Glyc[erin is] a triatomic alcohol, $C_3H_5(OH)_3$. Theoretically, therefore, the milk [wou]ld contain triglycerides of the fatty acids present, that is, there [would b]e tributyrin, triolein, tristearin, etc. In reality no such combination [exists.] Just in what order the triglycerides are present has not been [definit]ely established. The acids present in butter fat are butyric, caproic, [capryl]ic, capric, lauric, myristic, palmitic, oleic and stearic.

[Le]ll[1] holds that butter fat consists of mixed glycerides, glycerides in [each m]olecule of which the glycerol is combined with three different acid [radica]ls forming a compound having the following composition:

$$C_3H_5\begin{cases} OC_4H_7O \\ OC_{16}H_{31}O \\ OC_{18}H_{35}O \end{cases}$$

[T]his theory is supported by the fact that the glycerol forms triacid [compo]unds and not compounds of one acid, which theoretically could be [possib]le. If the glycerol formed monoacid compounds, butter fat would [contai]n glyceryl tributyrates, caproates, stearates, etc.

## SOLUBILITY OF BUTTER FATS IN ALCOHOL.

[I]f butter fat is dissolved in alcohol, from 1.1 to 3.3 per cent of the [fat go]es into solution, the solubility depending on the temperature of the [alcoh]ol. If tributyrin existed in butter fat, all of the tributyrin would

[1] The Chemistry of Foods, Vol. II, page 44.

go into solution.[1] Analyses of the portion soluble in alcohol show that this is not the case. Tables I and II give the value of the constants as determined for the portion soluble in cold alcohol, the portion not soluble in cold alcohol, but soluble in hot alcohol, and the portion not soluble in either hot or cold alcohol.

TABLE I.

| | Portion Soluble in Alcohol at 20 deg. C | Portion Not Soluble in Cold Alcohol, but Soluble in Alcohol at 75 deg. C. | Portion Not Soluble in Either Hot or Cold Alcohol |
|---|---|---|---|
| Reichert-Meissl Number | 48.1 | 29.6 | 20.7 |
| Melting point | 16.9°C. | 31.5°C. | 36.0°C. |
| Soluble acids (as Butyric) | 9.79% | 6.60% | 4.[illegible]% |

TABLE II.

| | At 20°C. | At 75°C. |
|---|---|---|
| Solubility of butter fat in 95 % alcohol | 1.1% | 3.3% |

The melting point of the portion soluble in alcohol at 20° C. is 16.9° C., while that of the portion not soluble in either hot or cold alcohol is 36° C., showing a difference of 19.1° C. The Reichert-Meissl No. in the portion soluble in alcohol is 48.1, in the portion not soluble in alcohol it is 20.7, showing a difference of 27.3. Since only 1.1 per cent of the fat is soluble in cold alcohol, this would indicate that no tributyrin exists in butter fat. This fact becomes still more evident by an examination of the molecular weight of the glycerides soluble in alcohol and those not soluble in alcohol as calculated from the figures in Table VII.

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[1] Cochran, "Action of Alcohol on Butter Fats," Analyst, Vol. 13, page 55. Lewkowitsch, "Oils, Fats and Waxes," Vol. II, page 675, 1909.

The saponification of a neutral fat yields a perfectly definite compound. This saponification takes place according to the following reaction for an ester with three molecules of acid combined with the radical of a trihydric alcohol:

$$C_3H_5\begin{cases} R_1 \\ R_2 \\ R_3 \end{cases} + 3KOH = C_3H_5(OH)_3 + K(R_1' + R_2 + R_3)$$

The molecular weight of the triglyceride is calculated as follows: Determine the per cent of KOH required to saponify the fat, and divide the molecular weight of 3(KOH) by the per cent thus obtained, or multiply the saponification equivalent by three.

Thus, from the figures in Table VII the saponification equivalent of the portion soluble in alcohol was found to be 216.5. This multiplied by 3 is 649.5. This equals the molecular weight of the triglyceride.

The saponification equivalent of the portion not soluble in alcohol was found to be 260.9; this multiplied by 3 equals the molecular weight. 782.7. The molecular weight of butyrin $C_3H_5(C_4H_7O)_3$ is 302, while the molecular weight of the triglycerides of the soft portion is 649.5.

The fact that only 1 per cent of the butter fat was dissolved in cold alcohol shows clearly the absence of tributyrin, otherwise the per cent of alcohol-soluble fat would be higher. The soft portion must, therefore, be made up of mixed glycerides of the acids found in butter fat, the acids having a low melting point and a low molecular weight predominating.

## FRACTIONAL SEPARATION OR CRYSTALLIZATION OF BUTTER FATS.

The same condition presents itself if butter fat is subjected to fractional separation. When butter fat is exposed to a temperature below the melting point of the harder glycerides, the softer glycerides separate from the harder glycerides. When this process is repeated by lowering the temperature after each separation, a separation can be effected whereby the constants differ widely from the original mixed glycerides.[1] Table III shows the variation of the constants of the fats thus separated. The butter used in this experiment was made in March.

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[1] Richmond Dairy Chemistry, page 37.

TABLE III.

*Composition of Portions of the Butter Fat Obtained by Fractional Separation.*

| | Original Butter Fat. | Soft Portion. | Hard Portion. |
|---|---|---|---|
| Reichert-Meissl Number | 29.06 | 32.65 | 26.74 |
| Iodine number | 34.97 | 42.10 | 30.11 |
| Koetts. saponification number | 229.5 | 233.87 | 228.8 |
| Refractive index at 40° C. | Reading 44.1<br>1.4552 | Reading 45.1<br>1.456 | Reading 43.1<br>1.4546 |
| Melting point | 34° C. | 14.5°C. | 37.2°C. |
| Per cent insoluble acids | 88.76 | 87.89 | 89.47 |
| Melting point of insoluble acids | 40°C. | 36.5°C. | 42.5°C. |
| Per cent soluble acids (as butyric) | 5.89 | 6.67 | 5.46 |
| Koetts. saponification number insoluble acids | 219.5 | 221.35 | 218.8 |
| Iodine number insoluble acids | 37.36 | 45.05 | 33.48 |

Later in the season (in May) another sample of butter was treated similarly, separating the liquid from the solid portions of the fat, and the constants were determined as shown in Table IV.

TABLE IV.

*Composition of Portions of the Butter Fat Obtained by Fractional Separation.*

| | Original Butter Fat. | Soft Portion. | Hard Portion. |
|---|---|---|---|
| Reichert-Meissl number | 30.00 | 33.85 | 24.66 |
| Iodine number | 39.82 | 43.55 | 33.08 |
| Koetts. saponification number | 230.1 | 232.78 | 226.4 |
| Refractive index at 40° C | Reading 44 1.4552 | Reading 44 8 1.4558 | Reading 43 1.4545 |
| Melting point | 32.5°C. | 13.2°C. | 38.1°C. |
| Per cent insoluble acids | 87.54 | 86.67 | 88.64 |
| Melting point insoluble acids | 39.2°C. | 35.3°C. | 42.4°C. |
| Per cent soluble acids (as Butyric) | 6.09 | 6.90 | 5.17 |
| Koetts. saponification number insoluble acids | 220.53 | 221.6 | 218.7 |
| Iodine number insoluble acids | 42.14 | 46.2 | 35.66 |
| Per cent glycerin | 12.58 | 12.89 | 12.33 |

Tables III and IV show that the soft portions contain more volatile or soluble acids, also a greater per cent of oleic acid in combination with the glycerol base than the hard portions. The melting point of the soft portions was 22.8° C. and 24.9° C., respectively, lower than the melting point of the hard portions.

The difference in the melting points between the soft and hard portions of the insoluble fatty acids was not as great as that of the soft and hard portion of the glycerides from which the insoluble acids were derived. The reason for this must lie in the fact that the soluble fatty acids have been removed and that, therefore, the melting points of the different portions of the insoluble fatty acids depend almost entirely on the per cent of oleic acid present.

The soft portion of the glycerides is made up of a higher per cent of acids with a lower melting point, i. e., oleic and soluble acids. The

[illegible] acids have a very low melting point. Therefore even a slight increase in the per cent of soluble acids must cause a lowering of the melting point.

Tables V-A and V-B show a comparison of the iodine number of the soft and hard portions of the glycerides and of the insoluble acids derived from the glycerides. The iodine number of the soft and hard portions of the insoluble acids is higher than that of the corresponding portions of the glycerides of the butter fat. This is natural. The soluble acids and glycerin have been removed from the glycerides, raising the per cent of the remaining constituents of the insoluble acids above that in the glycerides.

TABLE V-A.

*Iodine No. of Soft and Hard Portions of Butter Fat.*

| | Soft Portion Iodine Number | Hard Portion Iodine Number | Soft Portion Per cent Olein | Hard Portion Per cent Olein | Gain Iodine Number | Gain Per cent Olein. | Per cent Gain Olein of Soft Portion Over Hard Portion |
|---|---|---|---|---|---|---|---|
| From table III | 42.10 | 30.11 | 48.83 | 34.92 | 11.90 | 13.72 | 39.31 |
| From table IV | 43.55 | 33.08 | 50.518 | 38.37 | 10.47 | 12.148 | 31.6 |

TABLE V-B.

*Iodine No. of Insoluble Acids of Soft and Hard Portions.*

| | Soft Portion Iodine Number | Hard Portion Iodine Number | Soft Portion Per cent Olein | Hard Portion Per cent Olein | Gain Iodine Number. | Gain Per cent Olein. | Per cent Gain Olein of Soft Portion Over Hard Portion. |
|---|---|---|---|---|---|---|---|
| From table III | 45.05 | 33.48 | 52.25 | 38.84 | 11.57 | 13.41 | 34.5 |
| From table IV | 46.2 | 35.66 | 53.59 | 41.36 | 10.54 | 12.23 | 29.5 |

## CONCERNING THE SOLUBLE FATTY ACIDS.

Table VI shows the per cent of soluble fatty acids and glycerin in the soft and hard portions of butter fat. The soft portion contained 2.06 per cent more soluble acids and .56 per cent more glycerin than the hard portion, as obtained from data in Table IV.

TABLE VI.

*Per Cent of Soluble Acids and Glycerin in Soft and Hard Portions.*

| | Soft Portion. | Hard Portion. | Gain. |
|---|---|---|---|
| Per cent soluble acids | 8.23 | 6.17 | 2.06 |
| Per cent Glycerol | 12.89 | 12.33 | .56 |

The soluble acids were calculated on the basis of a mean molecular weight of 104.5. This molecular weight was calculated from the amount of glycerides of the soluble acids and other data taken from Table IV.

The glycerol ($C_3H_5$) is calculated from the per cent of soluble acids, mean molecular weight 104.5. From this calculation the per cent of glycerin $C_3H_5$ $(OH)_3$ is readily determined.

The general formula for one molecule of a triglyceride is $C_3H_5(R)_3$, where R stands for mixed acid radicals $R_3$=104.5X3=313.5; allowing for the basic hydrogen $C_3H_2$=38, then the molecular weight of the triglyceride $C_3H_5(R)_3$ is 351.5.

$$351.5 : 38 = 8.23 : X$$
$$X = .888\%\ C_3H_2$$

From these results the per cent of glycerin is calculated as follows, the molecular weight of glycerin being 92:

$$38 : 92 = .888 : X$$
$$X = 2.14$$

This is the per cent of glycerin combined with the soluble acids of the soft portion.

Likewise, the per cent of the glycerin combined with the soluble acids of the hard portion is calculated:

$$351.5 : 38 = 6.17 : X$$
$$X = .888\%\ C_3H_2$$
$$38 : 92 = .666 : X$$
$$X = 1.61$$

This is the per cent of glycerin combined with the soluble acids of the hard portion.

The difference between the per cent of glycerin combined with the per cent of soluble acids of the soft portion and the per cent of glycerin combined with the per cent soluble acids of the hard portion, then, is 2.14—1.61=.53%. This agrees closely with the difference of the glycerin between hard and soft portions as shown by analyses. (See Table VI.)

The per cent of glycerin combined with the insoluble acids is nearly the same in both soft and hard portions, because the per cent of insoluble acids in the soft and hard portions differs very little. Also the variation in the composition of the insoluble acids would not materially affect the molecular weight. Therefore, it is reasonable to expect that nearly the same per cent of glycerin is combined with the insoluble acids of both the soft and the hard portions.

## RELATION OF COMPOSITION OF BUTTER FAT SOLUBLE AND INSOLUBLE IN ALCOHOL TO COMPOSITION OF SOFT AND HARD PORTIONS OF FAT OBTAINED BY FRACTIONAL SEPARATION.

A comparison of the constants of the soft and hard portions with the constants of the fats soluble and insoluble in alcohol shows a close relation. The results are summarized in Table VII.

TABLE VII.

*Showing the Variation of the Constants of the Soluble and Insoluble Portions in Alcohol, Also of the Soft and Hard Portions of Butter Fat Taken for the Experiment.*

| | A | | | B | | |
|---|---|---|---|---|---|---|
| | Alcohol—Soluble Portion. | Alcohol—Insoluble Portion. | Original Butter Fat. | Soft Portion. | Hard Portion. | Original Butter Fat. |
| Reichert-Meissl number | 48.1 | 20.7 | 27.70 | 33.85 | 24.66 | 30.00 |
| Melting point | 16.9°C. | 36.°C. | 33.5°C. | 13.2°C. | 38.1°C. | 32.5°C. |
| Iodine number | 34.07 | 39.75 | 37.63 | 43.55 | 33.08 | 39.82 |
| Koetts. saponification number | 259.14 | 215.06 | 227.4 | 232.78 | 226.4 | 230.1 |
| Saponification equivalent | 216.5 | 260.9 | 246.79 | 241.1 | 248.3 | 244.0 |
| Refractive index at 40° C. | Reading 42.7 1.4543 | Reading 45.6 1.4563 | Reading 44.4 1.4555 | Reading 44.8 1.4558 | Reading 43 1.4545 | Reading 44 1.4552 |
| Per cent soluble acids (as Butyric) | 9.792 | 4.26 | 6.60 | 6.90 | 5.17 | 6.09 |

These data give the composition of the portions of fat soluble in alcohol and of the original butter fat; also the composition of the soft and hard portions of butter fat separated by fractional crystallization and of the original butter fat. The samples A and B of butter fat used for the two experiments were not taken from the same lot of butter.

The Reichert-Meissl No. is distinctly higher in the fat soluble in alcohol and in the fat of the soft portion, than it is in the fat insoluble in alcohol and in the fat of the hard portion, as well as in the original fat.

The melting point is lowest in both the fat soluble in alcohol and in the fat of the soft portion.

On the other hand, the iodine number is lowest in the fat soluble in alcohol and highest in the fat of the soft portion.

The figures in the above table show the influence of the constants on the melting point of butter fat. The portion of fat insoluble in alcohol and the original fat from which the above portion was taken show a decidedly higher iodine number than the portion soluble in alcohol. If the melting point depended solely on the iodine number, the melting point of the fat insoluble in alcohol and of the original butter fat would be distinctly lower than the melting point of the portion soluble in alcohol. Table VII shows that this is not the case. The melting point of the portion insoluble in alcohol and of the original butter fat is a great deal higher (19.1° C. and 16.6° C., respectively, higher) than the melting point of the fat soluble in alcohol. The only factor to which this fact can be attributed is the high Reichert-Meissl No. in the case of the fat soluble in alcohol, as compared with the low Reichert-Meissl No. of the fat insoluble in alcohol and of the original butter fat. These results make it perfectly clear that the softness or hardness (melting point) of butter fat is dependent to a great degree on the per cent of soluble fatty acids present.

This table further shows, as stated in the previous chapters, that butter fat is a mixture of triglycerides of different fatty acids. The soft portion is the result of mechanical separation at different temperatures. It, therefore, contains more glycerides combined with acids of low melting points including oleic and soluble acids. Furthermore, the fat soluble in alcohol represents glycerides of acids soluble in alcohol. Since it is known that some of the glycerides of the soluble acids are soluble in alcohol, we can assume that some of the molecules in butter fat are made up of the glycerides containing a larger proportion of the soluble acids than others.

## CONDITIONS AFFECTING THE COMPOSITION OF BUTTER FAT.

The composition of butter fat varies with the season of the year. A series of analyses of butter fat of butter made during each of the twelve months of the year, yielded the results summarized in Table VIII.

The results in Table VIII show that the Reichert-Meissl number was lowest in October, increasing steadily until it reached its maximum in March. After March it dropped abruptly, holding about its own till July, then taking a second drop and declining slightly toward October.

TABLE VIII.

*Effect of the Season of Year on the Composition of Butter Fat.*

| | Reichert Meissl Number. | Iodine Number. | Melting Point. |
|---|---|---|---|
| January | 30.03 | 31.20 | 33.4° C. |
| February | 30.58 | 31.97 | 33.5° C. |
| March | 31.30 | 31.94 | 33.5° C. |
| April | 29.35 | 35.83 | 33.3° C. |
| May | 29.55 | 36.48 | 32.5° C. |
| June | 29.56 | 38.23 | 32.45° C. |
| July | 28.90 | 37.10 | 31.9° C. |
| August | 27.13 | 38.99 | 32.1° C. |
| September | 27.19 | 35.36 | 33.0° C. |
| October | 26.54 | 34.27 | 33.2° C. |
| November | 28.36 | 30.65 | 33.4° C. |
| December | 29.62 | 30.30 | 33.6° C. |

The Iodine number was lowest in December, increasing slightly toward and including March; rising abruptly in April and continuing to rise up to and including June, then gradually declining toward October and dropping suddenly in November, followed by a slight drop in December.

The melting point followed, in general, the Iodine number reversedly. It was lowest in mid-summer when the Iodine number was highest, and it reached its maximum in December, when the Iodine number was lowest. The variations of the melting point, however, were not so abrupt as those of the Iodine number. A careful study of Table VIII suggests that, at times, the variations in the melting point may have been influenced strongly by the Reichert-Meissl number.

Experimental data produced in this country and abroad show unmistakably that the feed which the cows receive influences the per cent of olein in butter. Such feeds as cottonseed meal, bran, corn, overripe dry

fodders, etc., when fed in excess, tend to decrease the per cent of olein, while linseed meal, gluten feeds, succulent pasture grasses, etc., are conducive of raising the per cent of olein.

The volatile fatty acids do not seem to be appreciably affected by the feed the cows receive. They are influenced, however, by the period of lactation as shown in Tables IX and X.[1]

TABLE IX.

*Showing the Effect of the Period of Lactation on the Milk Fats.*

| TIME. | Reichert-Meissl Number. | Soluble Acids. | Insoluble Acids. |
|---|---|---|---|
| 1st month | 32.41 | 7.39 | 87 26 |
| 2d month | 29.48 | 7.07 | 87.99 |
| 3d month | 29.95 | 7.08 | 87.90 |
| 4th month | 29.97 | 7.11 | 87.72 |
| 5th month | 29.56 | 7.00 | 87.72 |
| 6th month | 29.21 | 6.82 | 88.19 |
| 7th month | 28.06 | 6.45 | 88.4 |
| 8th month | 25.32 | 5.84 | 88.6 |
| 9th month | 25.45 | 6.01 | 88.5 |
| 10th month | 27.45 | 6.26 | 88.1 |

[1] Hunziker. Proceedings of the Indiana Academy of Science, 1908, page 144.

TABLE X.

*Showing Effect of the Period of Lactation on the Milk Fats.*

| TIME. | Reichert-Meissl Number. | Soluble Acids Per Cent. | Insoluble Acids. Per Cent. |
|---|---|---|---|
| 1st month | 36.68 | 8.20 | 86.76 |
| 2d month | 35.75 | 8.09 | 86.74 |
| 3d month | 33.19 | 7.59 | 86.99 |
| 4th month | 33.80 | 7.56 | 86.95 |
| 5th month | 33.63 | 7 47 | 87.10 |
| 6th month | 33.57 | 7.55 | 86.94 |
| 7th month | 32.72 | 7.49 | 86.99 |
| 8th month | 31.63 | 7.25 | 87.41 |
| 9th month | 31.93 | 7.10 | 87.50 |
| 10th month | 32.03 | 7.12 | 87.46 |
| 11th month | 26.64 | 6.50 | 88.20 |
| 12th month | 30.48 | 8.86 | 87.69 |

The data in Tables IX and X represent results of experiments with three cows whose period of lactation commenced in October and November respectively. They were fed on a uniform ration throughout the entire period of lactation with the exception that in July (the 9th month after calving) they were turned out on pasture.

The above tables clearly show that the soluble fatty acids are highest immediately after parturition, or at the beginning of the period of lactation. Slight irregularities excepted, they decreased as the period of lactation advanced and were lowest toward the close of the period of lactation.

It so happens that in most localities the majority of the cows drop their calves in late spring, at a time when they also change from dry feed to succulent pasture. This explains why in early summer both the per cent of volatile fatty acids and the per cent of oleic acids increase and the melting point decreases.

TABLE III.

*Composition of Portions of the Butter Fat Obtained by Fractional Separation.*

| | Original Butter Fat. | Soft Portion. | Hard Portion. |
|---|---|---|---|
| Reichert-Meissl Number | 29.06 | 32.65 | 26.74 |
| Iodine number | 34.97 | 42.10 | 30.11 |
| Koetts. saponification number | 229.5 | 233.87 | 228.8 |
| Refractive index at 40° C. | Reading 44.1<br>1.4552 | Reading 45.1<br>1.456 | Reading 43.1<br>1.4546 |
| Melting point | 35° C. | 14.5°C. | 37.3C. |
| Per cent insoluble acids | 88.76 | 87.89 | 89.47 |
| Melting point of insoluble acids | 40°C. | 36.5°C. | 42.5°C. |
| Per cent soluble acids (as butyric) | 5.89 | 6.67 | 5.46 |
| Koetts. saponification number insoluble acids | 219.5 | 221.35 | 218.8 |
| Iodine number insoluble acids | 37.36 | 45.05 | 33.48 |

Later in the season (in May) another sample of butter was treated similarly, separating the liquid from the solid portions of the fat, and the constants were determined as shown in Table IV.

moisture content of butter made in early summer is due to the increase in the soft fats it contains.

The moisture-retaining property of the fats is largely dependent on their melting point. The lower the melting point, the greater is their power to mix with and retain water. Since the glycerides of the oleic and soluble fatty acids have a low melting point, it is reasonable that any increase in the per cent of these glycerides tends to increase the water-retaining properties of the butter.

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Purdue Experiment Station.

# On a New Complex Copper Cyanogen Compound.

By A. R. Middleton.

(Preliminary Note.)

When a cold concentrated solution of KCN is added to a cold concentrated solution of cupric chloride or sulphate, but not nitrate, greenish brown cupric cyanide is precipitated; the precipitate dissolves on further addition of KCN with formation of a claret red to violet red compound, much resembling potassium permanganate solution. Further addition of KCN destroys the color, with precipitation of white cuprous cyanide (presumably), which then dissolves in excess of KCN. First addition of concentrated cupric salt solution, or the solid salt, to concentrated KCN solution produces a brilliant violet color, instantly destroyed by further addition and quickly disappearing on standing. Further additions of copper salt give the red compound, provided the solution is kept nearly at 0°; otherwise cyanogen is evolved and the red compound is not formed. If the solutions are too concentrated or too dilute, the red compound is not formed. Solutions about one-half saturated appear to give the compound most readily and in largest amount.

Search through the available literature has revealed no reference to such a compound. It is quite unstable, decomposing to a brown solution on standing in a warm room over night; is instantly decomposed by strong and weak acids and bases and by pyridine; soluble in alcohol, but insoluble in chloroform, ether, benzene, toluene and carbon tetrachloride. Attempts to crystallize out the compound are in progress, and at the time of writing appear promising. The method pursued is as follows: Solid $CuCl_2.2H_2O$ was added in small amounts to KCN solution about one-half saturated, with constant shaking in ice water. After the red color reached a maximum, the solution was filtered, three volumes of 95% alcohol added and placed in the icebox in an exhausted desiccator. After 24 hours white opalescent scales separated, which, after washing with alcohol and ether and drying, present a metallic appearance somewhat resembling tinfoil. These contain copper and may be cuprous cyanide. The solution retained its red color unchanged and it is hoped that the compound can be crystallized out in form suitable for analysis.

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This is the per cent of glycerin combined with the soluble acids of the hard portion.

The difference between the per cent of glycerin combined with the per cent of soluble acids of the soft portion and the per cent of glycerin combined with the per cent soluble acids of the hard portion, then, is 2.14—1.61=.53%. This agrees closely with the difference of the glycerin between hard and soft portions as shown by analyses. (See Table VI.)

The per cent of glycerin combined with the insoluble acids is nearly the same in both soft and hard portions, because the per cent of insoluble acids in the soft and hard portions differs very little. Also the variation in the composition of the insoluble acids would not materially affect the molecular weight. Therefore, it is reasonable to expect that nearly the same per cent of glycerin is combined with the insoluble acids of both the soft and the hard portions.

## RELATION OF COMPOSITION OF BUTTER FAT SOLUBLE AND INSOLUBLE IN ALCOHOL TO COMPOSITION OF SOFT AND HARD PORTIONS OF FAT OBTAINED BY FRACTIONAL SEPARATION.

A comparison of the constants of the soft and hard portions with the constants of the fats soluble and insoluble in alcohol shows a close relation. The results are summarized in Table VII.

TABLE VII.

*Showing the Variation of the Constants of the Soluble and Insoluble Portions in Alcohol, Also of the Soft and Hard Portions of Butter Fat Taken for the Experiment.*

| | A | | | B | | |
|---|---|---|---|---|---|---|
| | Alcohol—Soluble Portion. | Alcohol—Insoluble Portion. | Original Butter Fat. | Soft Portion. | Hard Portion. | Original Butter Fat. |
| Reichert-Meissl number | 48.1 | 20.7 | 27.70 | 33.85 | 24.66 | 30.00 |
| Melting point | 16.9°C. | 36 °C. | 33.5°C. | 13.2°C. | 38.1°C. | 32.5°C. |
| Iodine number | 34.07 | 39.75 | 37.63 | 43.55 | 33.08 | 39.82 |
| Koetts. saponification number | 259.14 | 215.06 | 227.4 | 232.78 | 226.4 | 230.1 |
| Saponification equivalent | 216.5 | 260.9 | 246.79 | 241.1 | 248.3 | 244.0 |
| Refractive index at 40° C. | Reading 42.7 1.4543 | Reading 45.6 1.4563 | Reading 44.4 1.4555 | Reading 44.8 1.4558 | Reading 43 1.4545 | Reading 44 1.4552 |
| Per cent soluble acids (as Butyric) | 9.792 | 4.26 | 6.60 | 6.90 | 5.17 | 6.09 |

These data give the composition of the portions of fat soluble in alcohol and of the original butter fat; also the composition of the soft and hard portions of butter fat separated by fractional crystallization and of the original butter fat. The samples A and B of butter fat used for the two experiments were not taken from the same lot of butter.

The Reichert-Meissl No. is distinctly higher in the fat soluble in alcohol and in the fat of the soft portion, than it is in the fat insoluble in alcohol and in the fat of the hard portion, as well as in the original fat.

The melting point is lowest in both the fat soluble in alcohol and in the fat of the soft portion.

On the other hand, the iodine number is lowest in the fat soluble in alcohol and highest in the fat of the soft portion.

The figures in the above table show the influence of the constants on the melting point of butter fat. The portion of fat insoluble in alcohol and the original fat from which the above portion was taken show a decidedly higher iodine number than the portion soluble in alcohol. If the melting point depended solely on the iodine number, the melting point of the fat insoluble in alcohol and of the original butter fat would be distinctly lower than the melting point of the portion soluble in alcohol. Table VII shows that this is not the case. The melting point of the portion insoluble in alcohol and of the original butter fat is a great deal higher (19.1° C. and 16.6° C., respectively, higher) than the melting point of the fat soluble in alcohol. The only factor to which this fact can be attributed is the high Reichert-Meissl No. in the case of the fat soluble in alcohol, as compared with the low Reichert-Meissl No. of the fat insoluble in alcohol and of the original butter fat. These results make it perfectly clear that the softness or hardness (melting point) of butter fat is dependent to a great degree on the per cent of soluble fatty acids present.

This table further shows, as stated in the previous chapters, that butter fat is a mixture of triglycerides of different fatty acids. The soft portion is the result of mechanical separation at different temperatures. It, therefore, contains more glycerides combined with acids of low melting points including oleic and soluble acids. Furthermore, the fat soluble in alcohol represents glycerides of acids soluble in alcohol. Since it is known that some of the glycerides of the soluble acids are soluble in alcohol, we can assume that some of the molecules in butter fat are made up of the glycerides containing a larger proportion of the soluble acids than others.

## CONDITIONS AFFECTING THE COMPOSITION OF BUTTER FAT.

The composition of butter fat varies with the season of the year. A series of analyses of butter fat of butter made during each of the twelve months of the year, yielded the results summarized in Table VIII.

The results in Table VIII show that the Reichert-Meissl number was lowest in October, increasing steadily until it reached its maximum in March. After March it dropped abruptly, holding about its own till July, then taking a second drop and declining slightly toward October.

TABLE VIII.

*Effect of the Season of Year on the Composition of Butter Fat.*

| | Reichert Meissl Number. | Iodine Number. | Melting Point. |
|---|---|---|---|
| January | 30.03 | 31.20 | 33.4° C. |
| February | 30.58 | 31.97 | 33.5° C. |
| March | 31.30 | 31.94 | 33.5° C. |
| April | 29.35 | 35.83 | 33.3° C. |
| May | 29.55 | 36.48 | 32.5° C. |
| June | 29.56 | 38.23 | 32.45° C. |
| July | 28.90 | 37.10 | 31.9° C. |
| August | 27.13 | 38.99 | 32.1° C. |
| September | 27.19 | 35.36 | 33.0° C. |
| October | 26.54 | 34.27 | 33.2° C. |
| November | 28.36 | 30.65 | 33.4° C. |
| December | 29.62 | 30.30 | 33.6° C. |

The Iodine number was lowest in December, increasing slightly toward and including March; rising abruptly in April and continuing to rise up to and including June, then gradually declining toward October and dropping suddenly in November, followed by a slight drop in December.

The melting point followed, in general, the Iodine number reversedly. It was lowest in mid-summer when the Iodine number was highest, and it reached its maximum in December, when the Iodine number was lowest. The variations of the melting point, however, were not so abrupt as those of the Iodine number. A careful study of Table VIII suggests that, at times, the variations in the melting point may have been influenced strongly by the Reichert-Meissl number.

Experimental data produced in this country and abroad show unmistakably that the feed which the cows receive influences the per cent of olein in butter. Such feeds as cottonseed meal, bran, corn, overripe dry

fodders, etc., when fed in excess, tend to decrease the per cent of olein, while linseed meal, gluten feeds, succulent pasture grasses, etc., are conducive of raising the per cent of olein.

The volatile fatty acids do not seem to be appreciably affected by the feed the cows receive. They are influenced, however, by the period of lactation as shown in Tables IX and X.[1]

TABLE IX.

*Showing the Effect of the Period of Lactation on the Milk Fats.*

| TIME. | Reichert-Meissl Number. | Soluble Acids. | Insoluble Acids. |
|---|---|---|---|
| 1st month | 32.41 | 7.39 | 87 26 |
| 2d month | 29.48 | 7.07 | 87.99 |
| 3d month | 29.95 | 7 08 | 87.90 |
| 4th month | 29.97 | 7.11 | 87.72 |
| 5th month | 29.56 | 7.00 | 87.72 |
| 6th month | 29.21 | 6.82 | 88 19 |
| 7th month | 28.06 | 6.45 | 88.4 |
| 8th month | 25.32 | 5 84 | 88.6 |
| 9th month | 25.45 | 6.01 | 88 5 |
| 10th month | 27.45 | 6.26 | 88.1 |

[1] Hunziker. Proceedings of the Indiana Academy of Science, 1908, page 144.

### TABLE X.

*Showing Effect of the Period of Lactation on the Milk Fats.*

| TIME. | Reichert-Meissl Number. | Soluble Acids. Per Cent. | Insoluble Acids. Per Cent. |
|---|---|---|---|
| 1st month | 36.68 | 8.20 | 86.76 |
| 2d month | 35.75 | 8.09 | 86.74 |
| 3d month | 33.19 | 7.59 | 86.99 |
| 4th month | 33.80 | 7.56 | 86.95 |
| 5th month | 33.63 | 7.47 | 87.10 |
| 6th month | 33.57 | 7.55 | 86.94 |
| 7th month | 32.72 | 7.49 | 86.99 |
| 8th month | 31.63 | 7.25 | 87.41 |
| 9th month | 31.93 | 7.10 | 87.50 |
| 10th month | 32.03 | 7.12 | 87.46 |
| 11th month | 26.64 | 6.50 | 88.20 |
| 12th month | 30.48 | 8.56 | 87.69 |

The data in Tables IX and X represent results of experiments with three cows whose period of lactation commenced in October and November respectively. They were fed on a uniform ration throughout the entire period of lactation with the exception that in July (the 9th month after calving) they were turned out on pasture.

The above tables clearly show that the soluble fatty acids are highest immediately after parturition, or at the beginning of the period of lactation. Slight irregularities excepted, they decreased as the period of lactation advanced and were lowest toward the close of the period of lactation.

It so happens that in most localities the majority of the cows drop their calves in late spring, at a time when they also change from dry feed to succulent pasture. This explains why in early summer both the per cent of volatile fatty acids and the per cent of oleic acids increase and the melting point decreases.

## RELATION OF COMPOSITION OF BUTTER FAT TO COMPOSITION OF BUTTER.

During late spring and early summer, at a time when, as shown above, the Reichert-Meissl number and the Iodine number are high and the melting point is low, the butter-maker experiences usually considerable difficulty in manufacturing butter with a reasonably low moisture content. This coincidence has suggested to the writers that there may be a more or less intimate relation betwen the melting point of the butter fats and their power to absorb water during the process of butter-making. A series of experiments was, therefore, conducted bearing on this point. The results are shown in Table XI.

TABLE XI.

*Per Cent of Moisture Retained by Soft and Hard Fats Churned Separately.*

| | Per Cent Water. | | Per Cent Increase of Soft Over Hard |
|---|---|---|---|
| | Soft Fats. | Hard Fats. | |
| March butter | 43.84 | 24 76 | 77.02 |
| May butter | 50 62 | 24.78 | 104.28 |
| Average | 47.23 | 24.77 | 90.65 |

Table XI covers experiments in which soft and hard portions of butter fat (butter fat with a low and a high melting point) were separated from one another by fractional crystallization of the fats and by pressure. The soft and hard portions were churned separately under identical conditions, adding the same amount of water to each churning and churning at the same temperature.

Twelve separate churnings were made each, the March butter and the May butter. In the March butter the per cent increase of the moisture of the soft fats over that of the hard fats was 77.02. In the May butter the per cent increase of the moisture of the soft fats over that of the hard fats was 104.28. These figures unmistakably show that the soft fats are capable of taking up a great deal more moisture than the hard fats. They, therefore, can leave little doubt that the material increase in the

moisture content of butter made in early summer is due to the increase in the soft fats it contains.

The moisture-retaining property of the fats is largely dependent on their melting point. The lower the melting point, the greater is their power to mix with and retain water. Since the glycerides of the oleic and soluble fatty acids have a low melting point, it is reasonable that any increase in the per cent of these glycerides tends to increase the water-retaining properties of the butter.

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# On a New Complex Copper Cyanogen Compound.

By A. R. Middleton.

(Preliminary Note.)

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Search through the available literature has revealed no reference to such a compound. It is quite unstable, decomposing to a brown solution on standing in a warm room over night; is instantly decomposed by strong and weak acids and bases and by pyridine; soluble in alcohol, but insoluble in chloroform, ether, benzene, toluene and carbon tetrachloride. Attempts to crystallize out the compound are in progress, and at the time of writing appear promising. The method pursued is as follows: Solid $CuCl_2.2H_2O$ was added in small amounts to KCN solution about one-half saturated, with constant shaking in ice water. After the red color reached a maximum, the solution was filtered, three volumes of 95% alcohol added and placed in the icebox in an exhausted desiccator. After 24 hours white opalescent scales separated, which, after washing with alcohol and ether and drying, present a metallic appearance somewhat resembling tinfoil. These contain copper and may be cuprous cyanide. The solution retained its red color unchanged and it is hoped that the compound can be crystallized out in form suitable for analysis.

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# Determination of Endothermic Gases by Combustion.

By A. R. Middleton.

Endothermic gases such as ethylene and acetylene, even when mixed with sufficient air to form an explosive mixture, may be accurately and safely determined by combustion in a gas pipette provided the following conditions are observed: (1) Presence of a considerable excess of oxygen; (2) admixture with an exothermic gas; (3) slow admission of the combustible gases to the combustion pipette; (4) application of heat from below on the entering combustible gases; (5) reduced pressure. These conditions are secured by using a Winkler-Dennis gas combustion pipette, the platinum spiral being placed as near the juncture of the capillary with the pipette as possible without endangering the glass; mixing the endothermic gases with one to two volumes of pure hydrogen; and slowly leading this mixture into oxygen instead of the reverse as is usually done in combustion of the methane and hydrogen of illuminating gas.

The combustion is carried out as follows: The hydrogen used as a diluent is generated in a Hempel hydrogen pipette from zinc free from carbon; the requisite quantity is drawn into a burette, measured and transferred to a mercury pipette; a measured volume of acetylene or ethylene is then driven over into the hydrogen and the gases thus mixed drawn back into the burette. About 10 cc. more than the theoretical amount of oxygen required for the combustion is measured and transferred to the combustion pipette. The burette containing the mixed combustible gases over mercury is connected with the pipette and the level bulb of the latter so placed that the oxygen in the pipette is under a reduced pressure of one or two centimeters of mercury. The current is then turned on and the resistance so adjusted that the spiral is maintained at a bright red heat. The pinch-cock on the rubber connection of the burette with the capillary arm of the pipette is opened; the expansion of the oxygen by the heat from the spiral approximately balances the reduced pressure and little or no gas enters the pipette on opening the pinch-cock. The screw pinch-cock on the connecting tube of the burette and its leveling tube is then slightly opened and so adjusted that the flow of gas into the pipette is about 2 cc. per minute. After proper adjustment is effected

the apparatus requires no further attention until the combustion is ended.

If the inflow of combustible gases much exceeds the rate prescribed, a series of small explosions is likely to occur at the juncture of the capillary side-arm with the pipette, traces of carbon deposition are evident and the results are slightly low.

Some analyses of acetylene and explosive mixtures of acetylene with air are appended:

| Exp. No. | $C_2H_2$, cc. | $H_2$, cc. | $O_2$, cc. | Res. cc. | After KOH cc. | $CO_2$, cc. | $O_2$ Consumed, cc. | $C_2H_2$, %. |
|---|---|---|---|---|---|---|---|---|
| 1 | 20.0 | 30.0 | 80.0 | 55.0 | 15.0 | 40.0 | 65.0 | 100.0 |
| 2 | 10.0 | 30.0 | 54.2 | 34 3 | 34.2 | 20.1 | 40.0 | 100.5 |
| 3 | 2 0 | 50.0 | 52 6 | 26.8 | 22.8 | 4.0 | 29.8 | 100.0 |
| 4 | 30.0 | 30.0 | 100.0 | 70.3 | 10.8 | 59.5 | 89.2 | 99.2 |
| 5 | 30.0 | 15.0 | 100.0 | 77 8 | 18.4 | 59.4 | 81.6 | 99.0 |
| 6 | 15.0 | 30.0 | 69.0 | 46.6 | 16.6 | 30.0 | 52.4 | 100.0 |
| 7 | 15.0 | 30 0 | 70.0 | 47.4 | 17.4 | 30.0 | 52.6 | 100.0 |
| 8 | 10.2 | 25.0 | 50.9 | 33 4 | 13.0 | 20.4 | 37.9 | 100.0 |

Explosive mixtures of air and acetylene:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 15.0 | 30.0 | 50.6 | 35.2 | 13.4 | 21.8 | ............ | 72.6 |
| 2 | 15.3 | 30.0 | 51.0 | 34.6 | 12.5 | 22.1 | ............ | 72 2 |

Absorption by fuming sulphuric acid gave 72.0% and 72.3%.

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# METHODS IN SOLID ANALYTICS.

By ARTHUR S. HATHAWAY.

Define the "vector" $[h, k, m]$ as the carrier of the point $(x, y, z) = P$, to the oint $(x + h, y + k, z + m) = Q$, and show that the distance and direction cosines f the displacement $PQ$ are given by functions of the vector called its *tensor* and nit, $T[h, k, m] = \sqrt{(h^2 + k^2 + m^2)} = n$, $U[h, k, m] = [h/n, k/n, m/n]$.

Interpret the sum $[h, k, m] + [h', k', m'] = [h + h', k + k', m + m']$ as a esultant displacement, $PQ + QR = PR$, and the product $n[h, k, m] = [nh, nk, nm]$, s a repetition of the displacement.

Define the linear functions of $q = [x, y, z]$ as the "scalars" or "vectors" whose alues or components are linear homogeneous functions of the components of $q$, uch as $ax + by + cz$, etc. Hence, for a linear function $Fq$, $F(q + r) = Fq + Fr$, $Fq = F(nq)$.

Hence, for a bi-linear function $Fqr$, $F(aq + a'q', br + b'r') = abFqr + b'Fqr' + a'bFq'r + a'b'Fq'r'$.

A special scalar and vector bilinear function of $q = [x, y, z]$, $q' = [x', y', z']$ re defined.

$$Sqq' = xx' + yy' + zz' = Sq'q.$$

$$Vqq' = [yz' - zy', zx' - xz', xy' - yx'] = - Vq'q.$$

If $\theta$ be the angle between the displacements $q, q'$, these functions are interreted as,

$Sqq' = Tq \,.\, Tq' \,.\, \cos\theta$. $TVqq' = Tq \,.\, Tq' \,.\, \sin\theta$; and $Vqq'$ is a displaceent perpendicular to both $q$ and $q'$, in the same sense as the axis $OZ$ is perendicular to $OX$ and $OY$, *i. e.*, on one side or the other of the plane $XOY$.

The use of this material is illustrated in the following examples:

$A = (2, 3, -1)$, $B = (3, 5, 1)$, $C = (8, 5, 2)$, $D = (5, 7, 11)$.

1. Find the lengths and direction cosines of $AB$, $AC$, $AD$.

   Ans. $TAB = 3$, $UAB = [\frac{1}{3}, \frac{2}{3}, \frac{2}{3}]$, etc.

2. Find $\cos BAC$. Ans. $SUABUAC = \frac{16}{21}$.

3. Find area of $ABC$ and volume of $ABCD$.

   Ans. $\frac{1}{2}\, TVABAC = \frac{1}{2}\, 185$, $\frac{1}{6}\, SADVABAC = -13$.

4. Find the cosine of the diedral angle $C - AB - D$.

   Ans. $SUVABACUVABAD = \frac{-1}{37\sqrt{10}}$

5. Find the sine of the angle between $AD$ and the plane $ABC$.

   Ans. $SUADUVABAC = -\frac{6}{\sqrt{185}}$.

6. Find the projection of $AB$ on $CD$ and the distance between them.

Ans. $SABUCD = \dfrac{19}{\sqrt{94}}$, $SADUVABCD = \dfrac{78}{\sqrt{485}}$.

7. Find the equation of the line $AB$.

Ans. $AP = tAB$, or $\dfrac{x-2}{1} = \dfrac{y-3}{2} = \dfrac{z+1}{2}$ $(= t)$.

8. Find the equation of the plane $ABC$.

Ans. $SAPVABAC = 2x + 9y - 10z - 41 = 0$.

(a) The distance from this plane to $(x', y', z')$ is $SAP'UVABAC$, or

$$\frac{(2x' + 9y' - 10z' - 41)}{\sqrt{185}}.$$

9. The vector whose tensor and components are the moments of $AB$ about $C$ and about axes through $C$ parallel to $OX$, $OY$, $OZ$, is $VCAB = [2, 9, -10]$.

10. The work done by $CD$ in making the displacement $AB$ is $SABCD = 19$.

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# Motion of N Bodies.

By Arthur S. Hathaway.

The relative motion of n bodies, in any order of space, and subject to any law of mutual action, is given by

$$(1)\quad \ddot{\phi} = \phi\pi$$

where $\varphi$ is a matrix which transforms $n$ determining points of a reference space of order $n - 1$ into the positions of the $n$ bodies, and $\pi$ is a self-conjugate matrix, depending solely upon the ratios of the mutual reactions to the corresponding mutual distances.

The matrix $\phi$ is of order $n - 1$, if the motion of the bodies is within the reference space, and $\phi'$, the conjugate of $\phi$, annuls every direction of the reference space exterior to the space of the moving bodies. If the space which contains the moving bodies be greater than $n - 1$'st order the matrix $\phi$ must be of the same order, but must annul all directions outside of the reference space.

The reduced equations of motion are,

$$(2)\quad (\dot{\psi} + W)\,\psi^{-1}\,(\dot{\psi} - W) = 2\,(\ddot{\psi} - \psi\pi - \pi\psi),$$

$$(3)\quad \dot{W} = \pi\psi - \psi\pi,$$

where $\psi = \phi'\phi$, a function of the mutual distances, and W is a skew conjugate matrix, whose elements are to be found from the quadratic equations between them in (2), and thence substituted in the remaining equations of (2) and (3), giving a certain number of reduced equations of second and third order.

Another equation which is linear in the elements of W enables us to find reduced equations in third and fourth orders,

$$(4)\quad D_t\,(\ddot{\psi} - \psi\pi - \pi\psi) = \pi\dot{\psi} + \dot{\psi}\pi + W\pi - \pi W.$$

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# Direct Reading Accelerometers.

By C. R. Moore.

Every person is more or less familiar with the subject of acceleration or deceleration—changes of velocity—whether or not the laws governing the same or the mathematical expressions therefor are understood. Such everyday occurrences as passengers swaying to and fro partially suspended from street car straps, the hurry up that accompanies one's movements as he tries to reach the car door just as the motorman stops the car, are examples which prove this. Changes in the rates of motion are essential to all forms of transportation, and the more rapidly a car or train can be brought up to speed (or stopped) the shorter will be the time required between two points when a given number of stops must be made. Railway trains, street and interurban cars are therefore started and stopped as quickly as is consistent with reasonable comfort, in response to the demand of the traveling public for fast time.

It is the purpose of this paper to discuss briefly the laws of motion, and to describe a new device for measuring the rate of change of velocity, showing results of tests recently conducted in the Electrical Laboratories at Purdue University.

The author realizes at the outset that the subject of acceleration measurement is an old one and is rather reluctant to lay claim before this body of scientists that what is offered herein is new. However as far as his knowledge goes this device has not been used previous to this time. The scheme is brought to your attention for whatever consideration it may merit.

Before discussing accelerometers in detail, a brief study of just what is meant by acceleration and deceleration may be of value.

In Fig. 1 curve "D" shows distances plotted against time, the distances being taken as ordinates and the time as the abscissæ. The car is to be thought of as moving from a certain point "O," distances "d" being measured from that point at the end of the any time "td." It will be noted that during the first few time units after the car starts the distance passed through each successive unit is greater than that passed through during the preceding unit of time, i. e. the rate of motion is increasing. At the

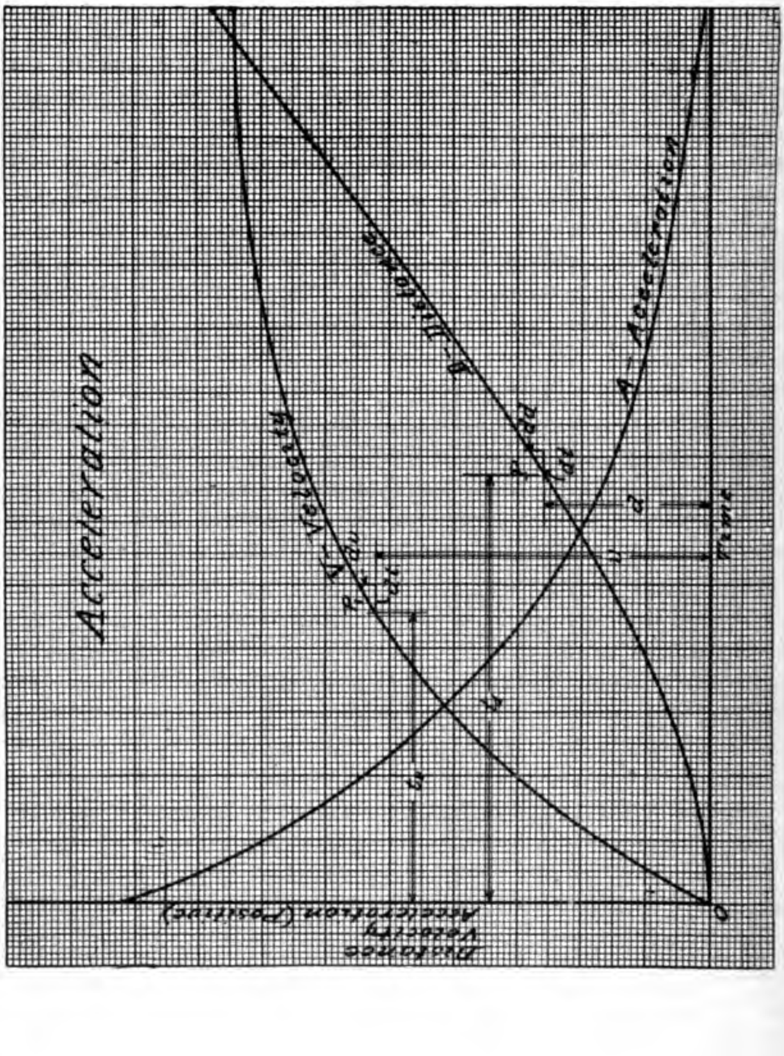
Acceleration
V - Velocity
B - Distance
A - Acceleration
Time
Distance
Velocity
Acceleration (Positive)

Fig. 1.

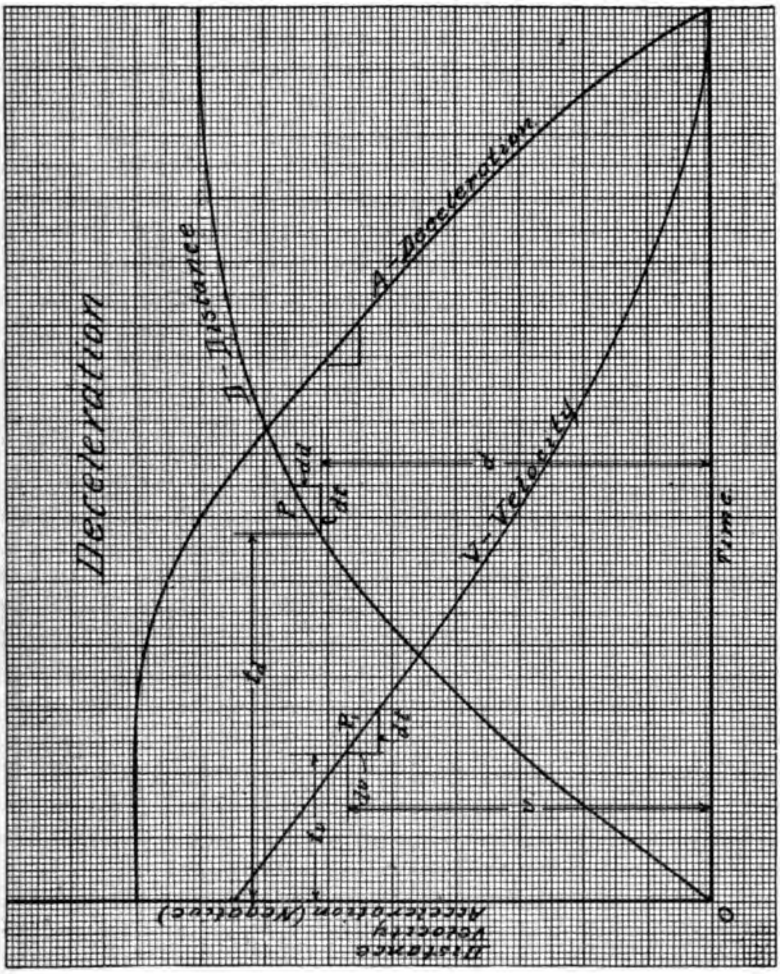
Deceleration
D-Distance
A-Deceleration
V-Velocity
Time
Distance
Velocity
Acceleration (Negative)
O

Fig. 2.

end of a certain time, however, equal increments of time show equal increments of distance. The curve then becomes straight because the rate of motion has become constant.

Velocity or the average rate of motion is defined as the space passed over divided by the time required for passage. The average velocity through any point then may be found by dividing small increments of distance by the corresponding increments of time. By taking these increments sufficiently small we may make the average velocity approach the true instantaneous velocity through any given point, as closely as we please. At the limit or when the increments become zero these velocities are equal.

Near the point "P" on the distance curves shown in Figs. 1 and 2 are drawn small triangles having for their vertical components small distances "dd" and for their horizontal components the corresponding increments of time "dt." From the above definition the average velocity for the space passed over designated by the small triangle will be $v = \frac{dd}{dt}$.

By taking this triangle very small the average velocity may be made to very closely approximate the instantaneous velocity at the point "P." It is also to be noted that the ratio $\frac{dd}{dt}$ is the expression for the tangent of the angle included between the line "dt" and that portion of the curve which completes the triangle. Values proportional to "v" may therefore be found at any point on the distance curve by drawing a tangent line at that point and finding the tangent of the angle between this line and the horizontal. Plotting these values multiplied by a constant gives the velocity curves "V" (See Figs. 1 and 2). From this curve we are able to determine the velocity of the car at any time "t."

By scanning curve "V" we note that the velocities for different time values until that time is reached where the distance curve became a straight line. At this point the tangent values become constant and the velocity curve becomes horizontal.

Just as velocity may be determined by dividing space passed over by the time required, so may the acceleration be determined by dividing the velocity change by the time required to make the change. The statements relative to average and instantaneous velocity also hold for average and instantaneous values of acceleration. We may therefore write $a = \frac{dv}{dt}$

as the general expression for acceleration when derived from the velocity-time curve. As before, this expression denotes tangent values so that the acceleration curve may be obtained from the velocity curve in the same manner as the velocity curve was obtained from the distance curve. It is interesting to note that the acceleration curve reaches the X-axis at the same time the velocity curve becomes horizontal and at the same time the distance curve becomes straight. This is shown mathematically as follows:

$$v = \frac{dd}{dt} \qquad a = \frac{dv}{dt} = \frac{d^2d}{dt^2} = 0 \text{ for } v = \text{a constant.}$$

or the value of "v" can be variable only so long as the distance time curve is not straight, and unless "v" is a variable the second derivative of the distance cure will be zero.

Physicists learned early that weight could not be taken as a standard of force on account of the variation of gravity with location on the earth's surface. Knowing however that force was required to change the velocity of a body it developed that when the amount of substance—mass—in a given body was known $(m = \frac{w}{g})$ the force needed to give it a definite change in velocity in a given time was a definite function of these two quantities. The familiar expression for this is, Force = mass × acceleration.

The equation is valuable to scientists and engineers alike. Using unit mass and unit acceleration, the scientist finds thereby a unit force which is constant. (The equation of the pendulum gives him the acceleration due to gravity at any point so that mass may be easily determined.) Knowing the masses involved in a given car or machine, the engineer is able to predetermine the torque necessary at the motor shaft to bring the same up to speed in a given time. This information is valuable for purposes of design.

After the apparatus has been assembled it is sometimes necessary to determine their performance. The mass being known it remains to measure the acceleration to see if the motors meet the requirements.

This measurement of acceleration has been attempted in many ways. A few of the more important schemes will now be considered. Accelerometers employing a freely moving mass of some sort have been most used. Dr. Sheldon's device is of this type, using a suspended weight carrying a pointer at the bottom (fastened thereto by rods) which plays over a scale.

The mass being free to move is sensitive to changes of velocity and the scale may be calibrated to read acceleration directly. The calibration is fairly simple and the device is not difficult to construct.

Another device working on the same principle consists of a "U" tube partially filled with mercury so placed that its plane is parallel to the motion of the car. It is obvious that changes of velocity will cause the mercury to rise in one side of the tube and to fall in the other. The more quickly these changes occur the greater will be the difference between the heights of the mercury in the two portions of the tube. The tube may therefore be calibrated to read acceleration directly.

Again the accelerometer takes the form of a slightly inclined track upon which rolls a ball. This track is made to extend in both directions and has a short level portion at the middle. Changes of velocity cause the ball to move one way or the other along the track. This device is difficult to read and is not very accurate.

All of these accelerometers are confined to horizontal motions and if the track be other than level corrections must be made therefor. This involves a great deal of labor and expense so that while the devices are simple in themselves their use is complicated. It is next to impossible to make them self-recording.

Another apparatus for reading acceleration consists of two magnetically actuated markers so arranged that dots may be made by each of them on a sheet of paper moved at a uniform rate of motion. The magnet of one of these pointers has its circuit closed through battery at regular time intervals by a clock. The other pointer has its magnet operated on a circuit which is closed through battery a definite number of times per revolution of the car wheel. From the record made by these pointers the acceleration at any time may be determined. This apparatus also involves a great deal of labor and expense and is seldom used.

The accelerometer which is the subject of this paper depends for its operation entirely upon electrical phenomena and is independent of its own location, motion or position. It will therefore read acceleration vertically or at any angle as well as in the horizontal direction. No corrections are necessary and it may easily be made self-recording. It is not difficult to calibrate and is permanent.

The circuit as originally conceived is shown in Fig. 3 in which "B" is an electric condenser, "C" an ordinary high grade direct current volt-

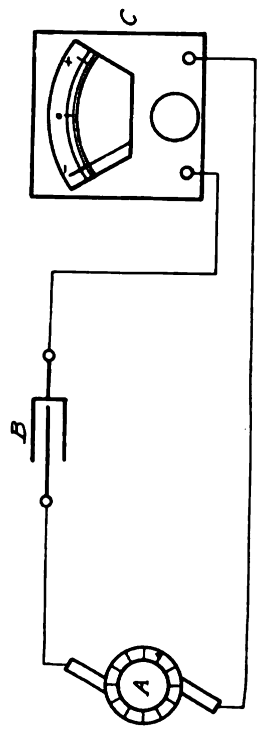


Fig 3.

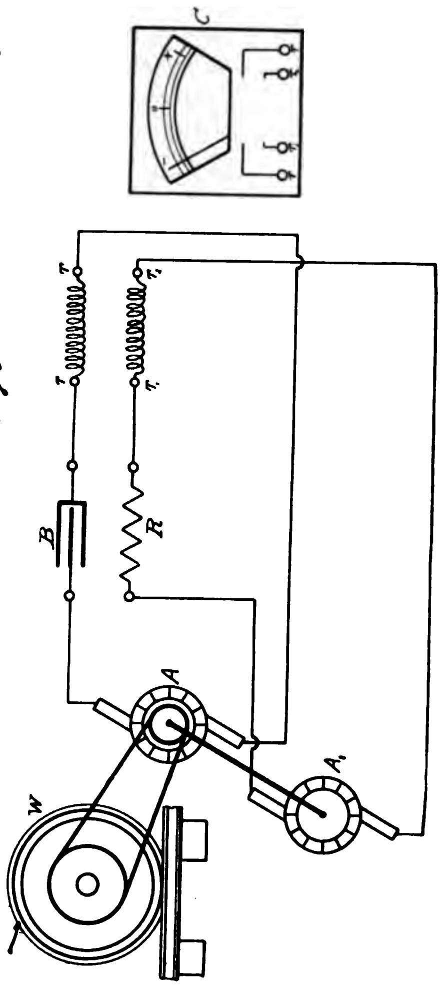


Fig. 4.

meter (with the extra resistance removed) and "A" is a direct current magneto generator having permanent magnet fields.

The equation of the condenser is Q=EC; where Q is the quantity of electricity in Coulombs (ampere seconds), E is the voltage impressed, and C is the capacity in farads of the condenser. Studying this equation we find that if E is increased uniformly the quantity of charge Q on the condenser plates will also increase uniformly. Since Q is increasing uniformly with respect to time, the inflow of current is at a constant rate. i. e., $i = \frac{dq}{dt}$. Likewise a constantly decreasing E will give a constant outflow of current. However, as soon as E reaches a fixed value all current flow in the circuit ceases since it is one property of the electric condenser to arrest the flow of direct current. (The terms "inflow" and "outflow" refer to those condenser plates that are directly connected to the instrument terminal. Of course as much current flows on to one set of plates as flows off of the other plates, the current in the line having a definite direction during an increase of voltage and the opposite direction during a decrease of voltage.) The magnitude of these currents are shown by the direct current instrument which consists merely of a coil swinging in a uniform magnetic field. So long then as the voltage is changing uniformly the instrument will read a constant value returning to zero only when E ceases changing. It follows that if E does not change uniformly the instrument will not read a constant value but that its indications will be proportional to the instantaneous rate of change of the voltage. The direct current magneto is so designed that its voltage is directly proportional to its speed, so that changes of voltage at its terminals can only occur as a result of changes in speed. Therefore the instrument reads the rate of change of speed, i. e. acceleration whether positive or negative.

In a preceding paragraph it was implied that an electric condenser allows no current to pass when the voltage E has reached a fixed value. This would be a fact if an ideal condenser could be made, but it is a well known fact that there is always some leakage even in the best condensers. This means that the dielectric has a definite value of resistance which varies with different conditions and substances, and according to Ohm's law the leakage current will be $I = \frac{E}{R}$. This state of affairs renders our ideal circuit incorrect for any speed above zero because the instrument gets a small current in a definite direction that is practically proportional

to speed, and even if the voltages were constant—acceleration zero—the instrument could not return to its zero position.

The circuit must therefore be modified to compensate for this small leakage current, as is shown in Fig. 4. A second direct current magneto (or another commutator on the original machine) is arranged so that it can feed current through a high resistance to another coil on the moving element of the instrument. This second coil is wound over the first and works in the same magnetic field. The current is passed through it in such a direction that the torque produced thereby opposes the torque of the original coil. By adjusting the high resistance these torques may be made equal and the instrument will read zero for any constant value of voltage within reasonable limits. This allows the charging currents to actuate the instrument entirely independent of the leakage current and condensers of reasonable cost may be employed.

In Fig. 4 the second generator is shown at $A_1$, the high resistance at R, and the second coil on the moving element of the instrument has its terminals shown at $T_1$ and $T_2$. These terminals are also shown in the separate sketch of the instrument C. It will be noted that the pair of magnetos are shown belted to a car axle. When this is done changes in the rate of motion of the car will produce changes in the voltages of the magnetos so that the instrument may be calibrated to read accelerations in terms of feet per second per second, as well as in terms of revolutions per second per second.

Figures 5 to 11 show the results obtained recently from tests on this type of accelerometer. Three curves (Figs. 5, 6 and 7) show positive acceleration, and three (Figs. 8, 9 and 10) show negative acceleration.

The experimental apparatus with which these results were obtained was made up as follows: the direct current machine in the condenser circuit was a separately excited generator of about 500 watts capacity having a normal speed of 1,800 R. P. M. The fields were excited from storage battery, about 140 milamperes being used. At 1,800 R. P. M. this excitation gave about 50 volts at the terminals. Since the field was constant and no appreciable current was taken from the armature the voltage remained directly proportional to the speed. The condensers had a combined capacity of about 65 micro-farads and were of the ordinary paper type. The instrument used was home made and very imperfect. Its moving element was very heavy, its frictional error large and the damping effect

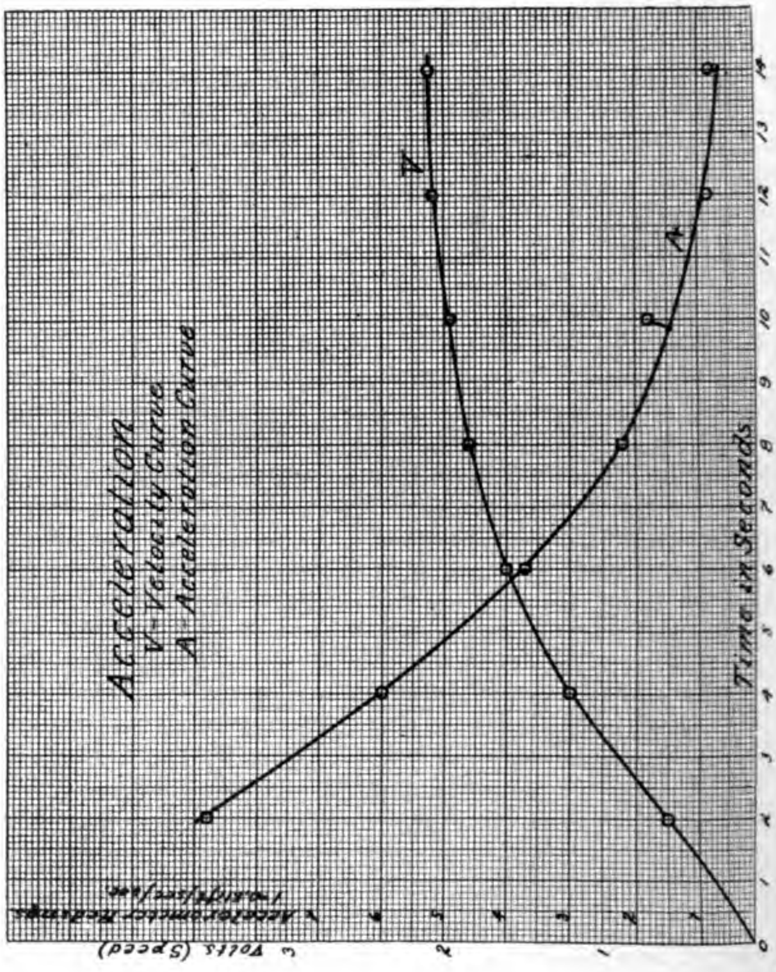
Acceleration
V-Velocity Curve
A-Acceleration Curve
V
A
Time in Seconds
Volts (Speed)
Accelerometer Readings

Fig. 5.

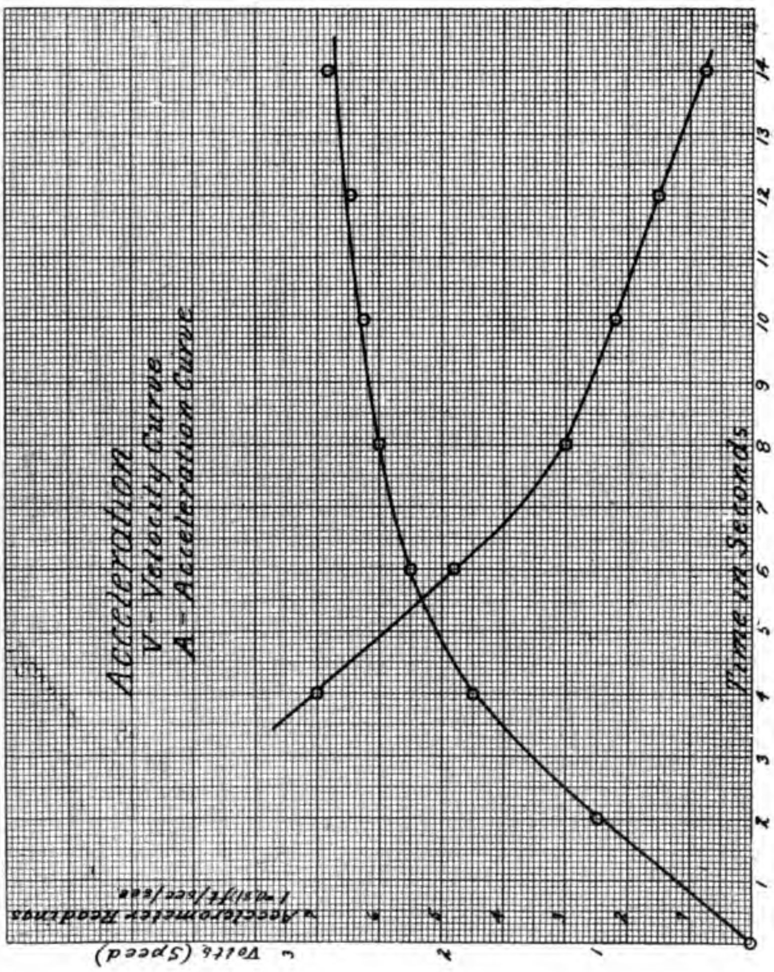
Acceleration
V - Velocity Curve
A - Acceleration Curve
Time in Seconds
Accelerometer Readings
Volts (Speed)

Fig. 6.

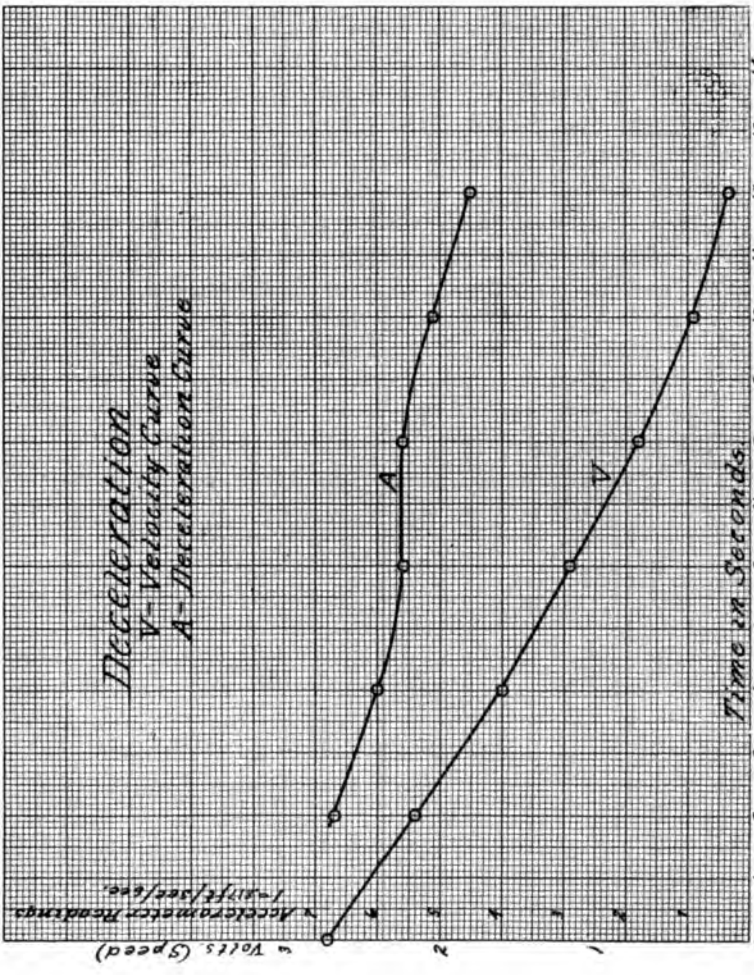
Deceleration
V-Velocity Curve
A-Deceleration Curve
A
V
Time in Seconds
Volts (Speed)
Accelerometer Readings
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Fig. 8.

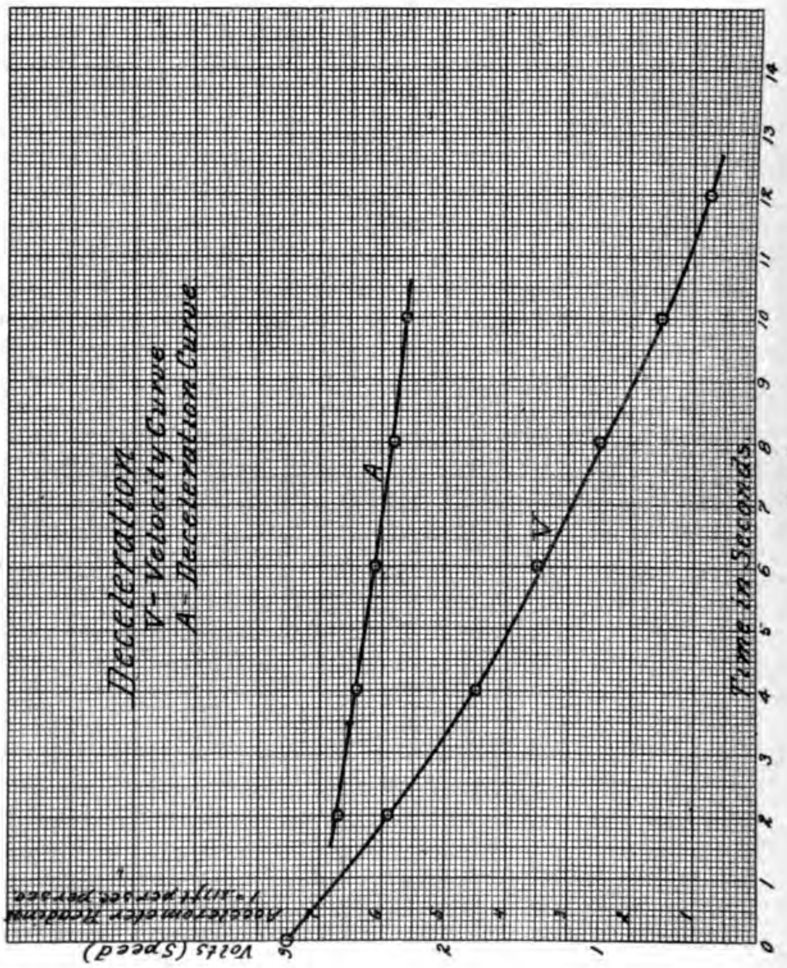
Deceleration
V-Velocity Curve
A-Deceleration Curve
A
V
Time in Seconds
Volts (Speed)
Accelerometer Reading

Fig. 9.

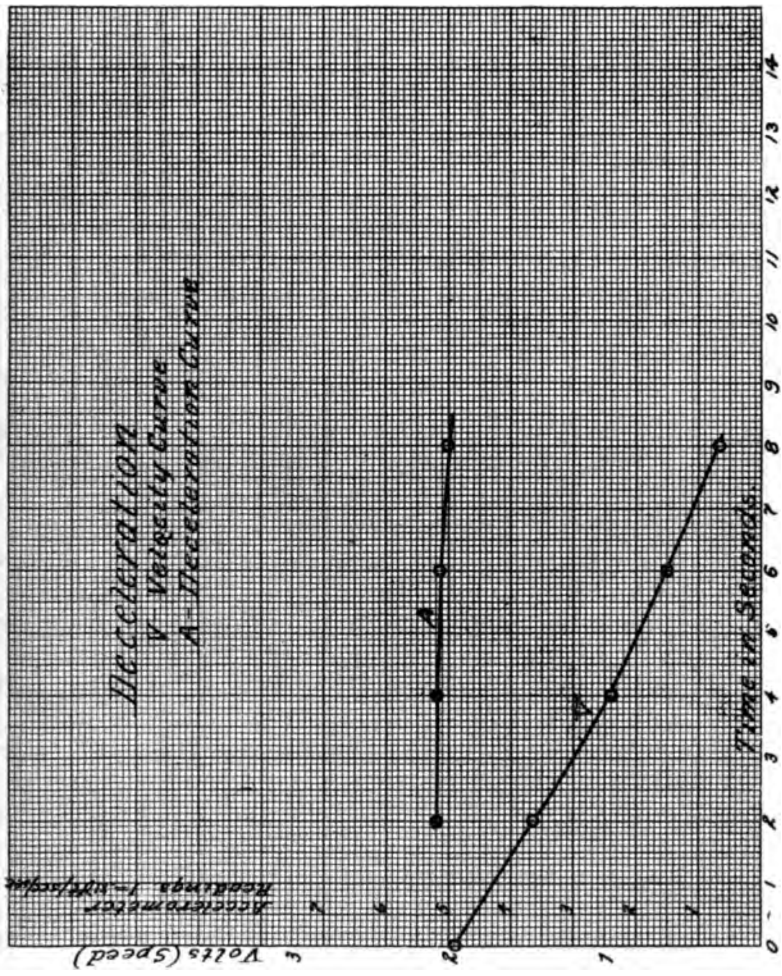
Deceleration
V Velocity Curve
A-Deceleration Curve
Time in Seconds
Volts (Speed)

Fig. 10.

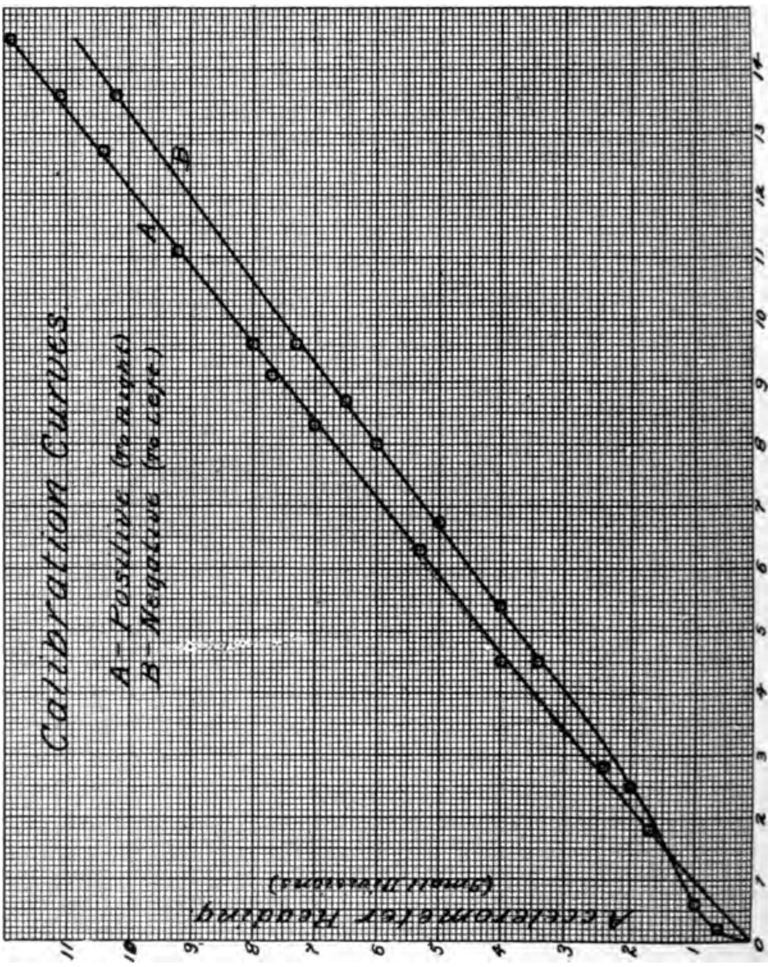
Calibration Curves.
A-Positive (to Right)
B-Negative (to Left)
Accelerometer Reading.
(Small Divisions)
A
B

Fig. 11.

poor. Its calibration curves are shown in Fig. 11. These imperfections account for the variation in its calibration constant as will be stated later. The resistance circuit contained a three-volt, 1,800 R. P. M. magneto (permanent fields) directly connected to the motor shaft, as was the generator in the condenser circuit. The resistance employed was of the ordinary box type.

Acceleration was obtained by impressing suddenly a fixed voltage on the driving motor and reading values of speed and the accelerometer every two seconds. Deceleration was obtained by opening the motor switch and reading speed and the accelerometer every two seconds. The speed readings were secured by attaching a voltmeter to the three-volt magneto. Some of the readings thus taken are shown in Figs. 5 to 10 which are self-explanatory.

Scanning these curves brings out their similarity to the mathematical curves on Figs. 1 and 2.

Calibration is effected by drawing tangents at various points on the speed time curve and dividing the accelerometer reading at this point by the value of the tangent of the angle between this line and the horizontal. This quotient should be constant. Now by noting actual voltage and the corresponding speed the number of volts per revolution may be obtained. Our tangent value indicates volts change in a given time "t" which may now be reduced to revolutions change in the same time. If the generators be belted to a car axle the wheels of which have a known diameter this revolution change may be reduced to the corresponding change of linear velocity in the given time "t."

For the tests herein described, however, the instrument scale was arbitrarily drawn and, with the particular circuit set up, each small division corresponds to an acceleration of 0.33 revolutions per second per second. If it had been used on an interurban car having 24" wheels its scale would indicate 0.817 feet per second per second per small division. This value could be reduced to a workable figure by using a larger condenser, a higher voltage and a more sensitive voltmeter.

These calibration values varied from 15 to 25 revolutions per second per second per small scale division on account of imperfections in the instruments and the small readings made necessary by having insufficient capacity.

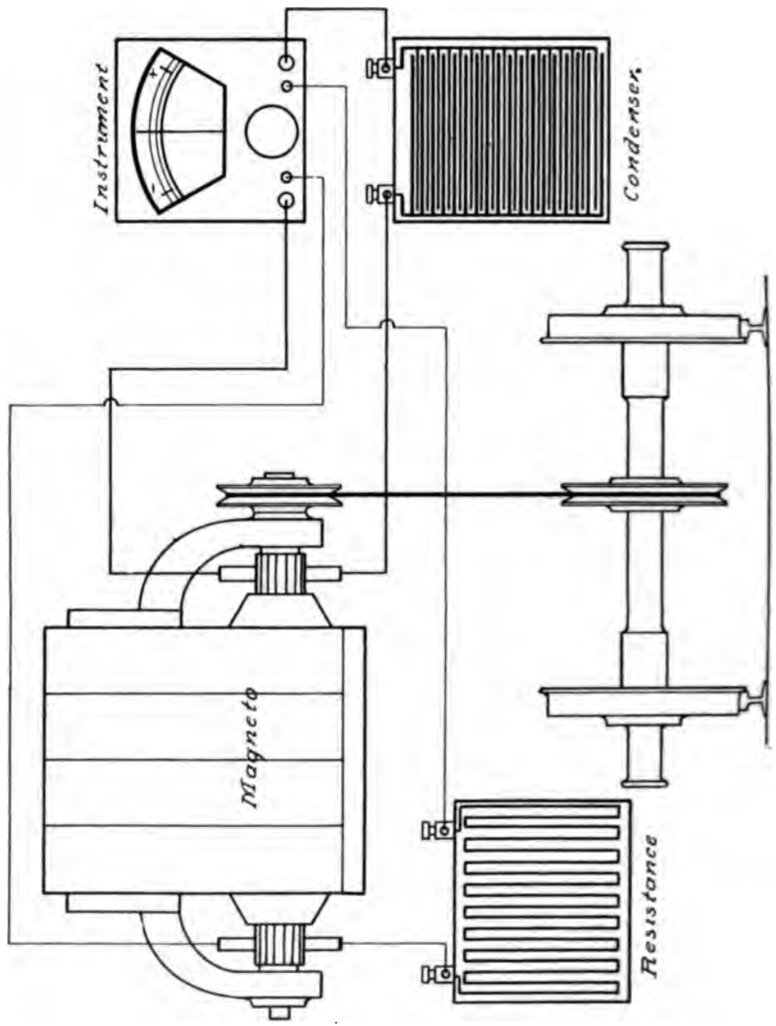


Fig. 12.

Almost any condenser when suddenly discharged if allowed to stand a few minutes will experience a rise in potential at its terminals. This rise is due to what is known as the residual charge. This phenomenon is explained as follows: When a condenser is charged its dielectric is strained and being non-homogeneous the strains are unequal. (By strain is meant the actual compression of the plates.) When discharged these strains are relieved but they do not decrease at the same rate, so that some parts of the dielectric become strained in the opposite sense and balance those parts which are slower in acting. The condenseer is then apparently discharged, but after standing a while these strains tend to diminish and usually there is a resultant strain set up. This resultant strain is due to the fact that while the forces were originally balanced at the end of the first discharge, yet the distances are unequal and in nonhomogeneous materials stress is seldom proportional to strain.

The condenser may now be discharged again and after a time may show still another rise of potential. In the apparatus herein described this effect is entirely negligible, for the reason that the condenser is never charged or discharged suddenly, some few seconds being required to complete the action.

In all condensers there is also some absorption, but with good condensers used at the voltages proposed for this apparatus this effect is also quite negligible, and we may with certainty say that for a given voltage change at any part of the potential range equal quantities of electricity pass through the instrument.

With an instrument giving a uniform scale therefore we have an apparatus which will show equal increments of readings for equal rates of change of velocity, i. e. a direct reading accelerometer.

Fig. 12 shows the apparatus as assembled for use in railway work. The double commutator magneto is here shown belted directly to the car axle. It is obvious that the readings of the instrument are unaffected by grades or side tiltings of the car.

The apparatus may be made self-recording by employing a recording instrument instead of an indicating one, as shown in Fig. 13. These recorders may be obtained in the market and are very sensitive and reliable. The record is made by placing a pen on the end of the voltmeter pointer, the whole being pulled down upon a sheet of paper moving at a uniform rate of motion by means of a small magnet whose circuit is

closed through battery by a clock. The record is thus made automatically and needs no correction.

The accelerometer may be made self-contained and is easily transferred from one car to another.

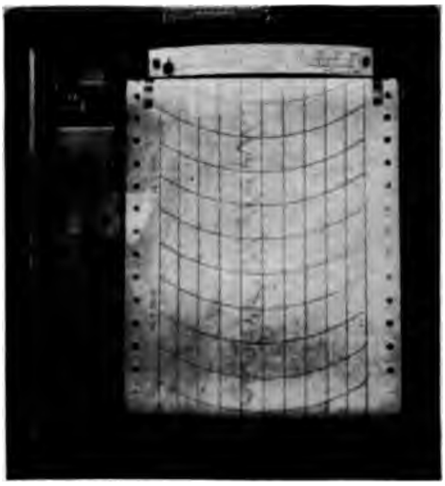

Fig. 13.

Before closing, the author wishes to express his appreciation of the efforts of Messrs. F. C. Weaver, G. T. Shoemaker and E. E. Thomas, members of the present Senior Electrical Class at Purdue University, whose kindly assistance made this paper possible.

Purdue University,
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# Some Notes on the Strength of Concrete Building Blocks.

By H. H. Scofield.

The concrete building block industry is rapidly assuming an important position and is now established on a firm basis among the other industries supplying building materials.

Reinforced concrete is now very largely used and seems to be the best form of concrete used for floors, beams and columns, but the concrete block seems to be the form of concrete most adaptable for use in the walls of residences and other buildings.

The industry has grown so rapidly in the past few years that standard specifications for their manufacture and use have been adopted by the National Association of Cement Users and by many cities of the United States. The need for proper specifications was brought about mainly on account of the large number of inferior blocks placed on the market by irresponsible manufacturers. The causes for this are various, such as: a desire for higher profits brought about by using inferior ingredients; ignorance as to the best methods of using the materials at hand, careless workmanship and improper treatment as to storage, etc.

The specification for crushing strength as called for by most specifications is so high that it can be filled only by the best methods and the best material, and although it is many times more than a block will ever be called upon to stand in actual use in a wall, yet it insures a block which is strong, dense and thereby water-proof, with clean-cut, smooth edges, and a block which will endure for ages.

The following are some items which enter into the making of good concrete blocks:

In the selection of a cement, a maker has two alternatives. He must either use a first-class, standard brand of known excellence, or he may use the competitive brands on the market, thereby getting lower prices. In the latter case, he should have each shipment sampled and tested by a reliable testing laboratory.

An unsound cement may not show up till the block is in the wall or for years after, but it is practically inevitable that the block will finally

crack and disintegrate. Some cement companies take proper precautions in the treatment of raw materials and storage of the finished product, such that very rarely does an unsound cement leave their mill. Other companies, in the rush of business, do not properly mix and grind their raw material and finished cement, and do not store the cement long enough for the hydration of the free lime present. These are conditions that tend to place more or less unsound cement on the market. The future of the concrete block manifestly depends to a great extent upon the use of a sound cement.

For maximum strength in concrete, the cement must be finely ground, but fine grinding is expensive and consequently this part of the manufacture is often slighted. The cement should also be slow setting, as a cement that reaches its initial set in two or three hours will be stronger at the end of seven days or a month than a quicker setting cement that reaches its initial set in forty or fifty minutes.

The cement to be used in concrete blocks should in all cases pass the specifications of the American Society for Testing Materials.

Too frequently the reason for poor concrete is ascribed to poor cement, and no thought is given the other materials entering in, namely; sand, gravel or broken stone. The selection and proportioning of the aggregate for the best concrete is very important in the building block industry. It is well known that the proportions of cement, sand and stone which will give the densest mixture of concrete will also give the highest strength. It is also recognized that a rich, dense mixture of concrete is the most nearly waterproof that concrete alone can be made. So that for a strong, water-proof block, it is important that the cement and aggregate be properly proportioned. This may be done by actual trial mixtures to determine the densest concrete. An aggregate containing coarse stones and sand has greater density than sand alone and consequently is better for use in concrete blocks.

According to Wm. B. Fuller, an eminent authority on concrete, the most nearly perfect gradation of sizes of particles in an aggregate may best be known by the process of mechanical analysis and subsequent reproportioning. In case the business warrants it, samples of the gravel should be submitted to a reliable testing laboratory for mechanical analysis to determine the proper proportions.

A dirty gravel or one that contains impurities should be washed. This will not only improve the strength of the concrete, but will make a more uniform and desirable color for the finished block.

It is now agreed that cement hardens by a process of crystallization of the active elements. Water must be present for the crystallizing to go on. Therefore it is necessary that the proper amount of water be used in mixing the concrete. This, by some authorities, is from 8 to 18 per cent. Also it is necessary that after moulding, the block must not be allowed to dry out, as no subsequent addition of water will give perfect crystallization. Some makers cure their blocks in a steam bath, thereby insuring constant moisture. The economical value of steaming concrete blocks is a subject for experiment as yet. Most specifications limit the time after making at which blocks may be used in the wall, so that the increased speed of hardening by the steam process is not so important.

The specification for crushing strength of concrete blocks, in most cases, is 1,000 pounds per square inch of gross area, no allowance being made for the hollow spaces. The block must reach this strength in 28 or 30 days after making.

The city of Indianapolis has recently adopted specifications for concrete building blocks, and the results of the first series of tests for the block makers of that city by the Laboratory for Testing Materials of Purdue University, indicate a chance for improvement.

Of 75 tests of blocks, supposed to have been made under the specifications, only 28 per cent. passed the specification for crushing strength, and the average age of these was 41 days instead of 30. Similar results have no doubt been found in all cities which have adopted a building block ordinance. However, under the influence of these somewhat rigorous specifications, it is to be expected that the quality of the product on the market will greatly improve. This in itself will strengthen the industry for those makers who are content to manufacture good blocks at a reasonable profit.

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# Polarization of Cadmium Cells.

By R. R. Ramsey.

While working on another problem (Phys. Rev. Vol. 16, p. 105) it was noted that the E. M. F. of a cadmium cell was greatly decreased and at times apparently reversed after a considerable quantity of electricity had passed through it.

To investigate the cause of this phenomenon the experiments described below were undertaken. Work of a similar nature has been carried out by F. E. Smith (Phil. Trans. Roy. Soc. Lon., Series A, Vol. 207, p. 393); by S. J. Barnett (Phys. Rev. Vol. 18, p. 104, 1904), and by P. I. Wold (Phys. Rev., Vol. 27, p. 132, 1909). However, in their experiments the time of polarization was comparatively small, the attention of the investigators being directed to the initial polarization or to the rate of recovery. In my work I have attempted to find the cause of this polarization.

Cells were constructed of the H type and according to the accepted formula for cadmium cells. The chemicals used were C. P. chemicals of commerce. With ordinary care a cell could be obtained whose E. M. F. did not differ more than .001 volt from the standard value. Measurements of E. M. F. were made by means of a potentiometer. At times where rapid measurements were desirable and great accuracy was not necessary a voltmeter was used, the readings being corrected for the internal resistance of the cell. Current was measured with a milliameter and time was measured with a watch. At first it was thought that the polarization was a surface effect, that a relation existed between the area of the surface of the electrode and the quantity of electricity required to polarize a cell to some standard amount. Cells were made with electrodes of various diameters. The current was noted at stated intervals, so that the total quantity could be caluclated. This was found to differ in different cells, but it appeared to depend more upon the past history of the cell than upon the electrode surface exposed.

It was found that after a cell has been polarized once and has regained its normal E. M. F. again it required less quantity of electricity to polarize it than it did during the first run. A cell with three legs was

made. Two of the legs were filled with mercury and the third was filled with cadmium amalgam. Connection was made to the amalgam terminal and to one of the mercury terminals and current passed until the cells were polarized. Measurements were made by means of the potentiometer, and it was found that the E. M. F. between the unpolarized mercury terminal and the cadmium terminal was normal, while the polarized mercury terminal gave a very small value, showing the polarization to be at the mercury terminal. Measurements were made between polarized cells and unpolarized cells by connecting the two cells together by means of a siphon filled with cadmium sulphate solution. In every case it was found that the polarized mercury terminal gave low values, while the polarized cadmium terminal gave normal values when connected to unpolarized mercury terminals, never deviating more than could be explained by concentration and temperature effects.

A cell (5) was short circuited for some days and part of the mercury was removed with a pipette, washed and filtered through a pinhole and made the mercury terminal of a new cell (6) from which the mercurous sulphate was omitted. The E. M. F. was measured from time to time and the recovery noted. The following table gives the results.

| | E. M. F. (5) | E. M. F. (6) |
|---|---|---|
| March 9, 5:15 p. m. | 0.1308 | 0.1290 |
| March 10, 9:00 a. m. | .1320 | .1307 |
| March 10, 3:45 p. m. | .1363 | .1310 |
| March 12, 9:20 a. m. | .1488 | .1330 |
| March 13, 10:15 a. m. | .1675 | .1322 |
| March 14 | 1.0222 | .1317 |
| March 15 | 1.0242 | .1335 |
| May 14 | 1.0146 | .0691 |
| June 8 | 1.0177 | .0533 |
| August 26 | 1.0189 | .0637 |
| September 24 | 1.0150 | .0462 |

The above table shows that cell (5), which contained mercurous sulphate, recovered its E. M. F. in a few days, while (6) remained polarized for six months. The results show the E. M. F. in March to be greater than the later values. This may be due to the cadmium sulphate solution not being concentrated in the early observations or to some constant error of the potentiometer. The table shows that the polarization is due to

something in the mercury which can not be washed or filtered out. But is removed by mercurous sulphate. The mercury from cell (6) was taken out and placed in a tube and sparked by a large electric machine. Cadmium lines were very distinct in the spectrum. Thus it would seem that polarization is caused by cadmium being deposited in the mercury and that the recovery is due to the removal of the cadmium by the mercurous sulphate.

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Bloomington, Ind.

# An Investigation of a Point Discharge in a Magnetic Field.

By Oscar William Silvey.

Since the announcement of the magnetic deflection of the electric arc and of the path of the particles of a vacuum tube discharge, there has been some investigation of the electric discharge in a magnetic field at atmospheric pressure.

Among the first of these investigations was that of Precht,[1] who found that when a spark passed transverse to the lines of force in a magnetic field, between a point anode and a blunt cathode, there was a deviation of the path of the spark, especially from the middle portion of the spark gap to the cathode, the spark increased in brightness, and there was a decrease in the fall of potential between the electrodes. Also, if the electrodes were separated farther until a brush discharge existed between them, the stream showed a deflection, the potential between the points decreased, and the brush often changed into a spark discharge, when the electro-magnets producing the field were excited. In case of the glow discharge, where there existed a small brush at the anode and a bright spot on the cathode, with the intervening space dark, the spot moved up or down according to the electrodynamic laws, when the field was magnetized first in one direction and then in the other.

In case a point cathode was used with a blunt anode, the spark was deflected and the potential raised, when the magnet was excited the spark discharge being often changed to a brush.

[2]H. E. Schaeffer has recently studied the effect of the magnetic field on the spark discharge of an induction coil in each of the following types of spark:

"1. The spark obtained when neither capacity nor self-induction had been introduced into the secondary circuit of the induction coil.

"2. The spark obtained when a capacity of 0.005 to 0.012 microfarads had been introduced into the secondary circuit.

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[1] J. Precht, Wied. Annalen (66-4, pp. 676, 697), 1898.
[2] H. E. Schaeffer, Astro-Physical Journal (28, pp. 121-149), Sept., 1908.

"3. The spark obtained when a capacity of .0006 to .012 M. F. and a self-induction of [illegible] henrys has been introduced into the secondary circuit."

In this study it was found that "when the magnetic field was parallel to the spark length, the first type of spark presented two sheets of vapor in the form of spirals. In a field at right angles to the spark length this vapor is in the form of two semicircular sheets, one being on each side of the spark gap in a plane perpendicular to the direction of the magnetic field.

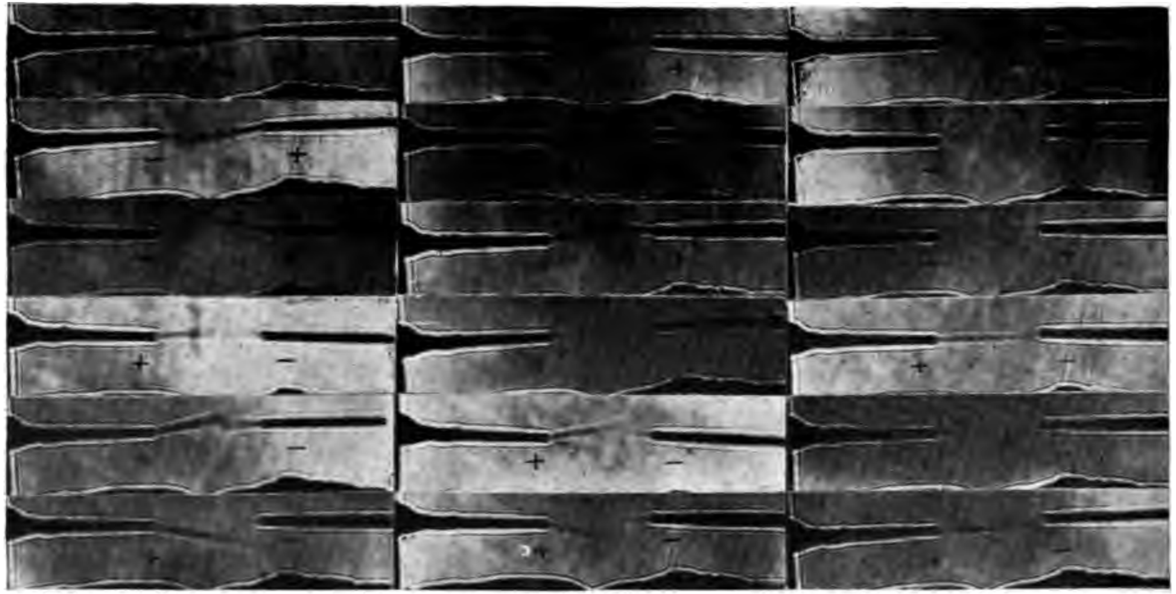
"In the second type of spark (if the capacity did not exceed .002 M. F.) and in the third type brilliant spiral threads in a parallel field and brilliant circular threads in a transverse field took the place of the spiral and circular sheets respectively. In the first and second types of spark the bundle of threads across the gap could not be deflected by a magnetic field of 12,000 gausses. In the third type the metallic vapor and the threads across the gap were deflected in a very strong field and in a manner analogous to that of the circular and spiral threads. Reversing the direction of the magnetic field, or that of the current through the primary of the induction coil, changes the position of the sheets and of their ends. Decreasing the current through the primary or lengthening the spark gap sufficiently, causes one sheet or one set of threads to disappear."

The different parts of the deflected spark were analyzed by the spectroscope, and it was found that the "Circular sheet of the first type of spark gave a spectrum of nitrogen bands, while the central threads showed that of the metallic lines and the air lines. The second type gave the same spectrum of bright air lines, and fainter metallic lines, for both circular threads and central threads. The third type showed the same spectrum (air lines) for all metals used as electrodes. The spectrum of the circular threads showed the arc lines in addition to the air lines."

By means of a rotating mirror, the velocity of the circular threads of the spark was determined, and from this a value for $\frac{E}{M}$ calculated.

Prof. A. L. Foley[1] passed transversely through a long tube which served as a pinhole camera an electric discharge and observed that when a photographic plate was placed at the opposite end of the tube from the pinhole, the plate after exposure showed a shadow picture of a stream

[1] Not yet published.



No. 1. No. 2. No. 3. No. 4. No. 5. No. 6.

A. B. C.

No. 1. Current first direction; magnetism (none).
No. 2. " " " " 1st direction.
No. 3. " " " " 2d "

No. 4. Current second direction; magnetism (none).
No. 5. " " " " 1st direction.
No. 6. " " " " 2d "

between the points which were used as electrodes. The picture of this stream was surrounded by interference or diffraction fringes, in some ways resembling the fringes about the solid points themselves.

The principal object of the present investigation was to study the effect of a magnetic field upon this stream and to study the character of the particles composing it.

The apparatus used was that constructed by Prof. Foley and Mr. Haseman for the investigation of interference fringes about a point discharge, air streams, and vapor streams. It consisted of a wooden tube 6.87 meters long (Fig. 1). One part 20.3x20.3x230 cm. was made to telescope over another part 15.2x15.2x457 cm. This provided a means of separating the two parts for adjusting the points and magnets. Another portion (E., Figs. 1 and 3) containing a plate holder (F) was made to fit over the end. The tube was painted a dead black inside, and at intervals screens (Fig. 9) were placed throughout the tube so that no light would be reflected from the sides. An opening was made in the lower side of the tube beneath the points and through this opening a magnet was introduced so that the lines of force were perpendicular to the direction of the line of discharge. During the latter part of the experiment a similar opening was cut in the top of the tube and a second magnet placed above the first one so that like poles faced each other. Figs. 4, 5, 6 and 8, show the successive attempts to increase the field strength. The end of the tube (C) was closed by a cap which shut out all light except from a pin hole, as shown by Fig. 2. A circular disc with holes of various sizes provided a means of regulating the amount of light. A is a 90° arc lamp, the crater of which is focussed on the pin hole by the lens B.

Light was shut out of the tube by placing a piece of black card board in front of the pin hole. When a photograph was to be taken, if the discharge was a silent or brush, the slide (S) was drawn from over the plate, and after the tube had come to rest, the card board was removed until the plate was sufficiently exposed. In case of the spark discharge which fogged the plate if exposed too long, the card board was first removed and the exposure made by withdrawing the slide.

The points first used were made of sharply pointed brass pins 0.61 mm. in diameter and 3 cm. long. In the latter part of the experiment the brass pins were replaced by steel millinery needles 0.70 mm. in

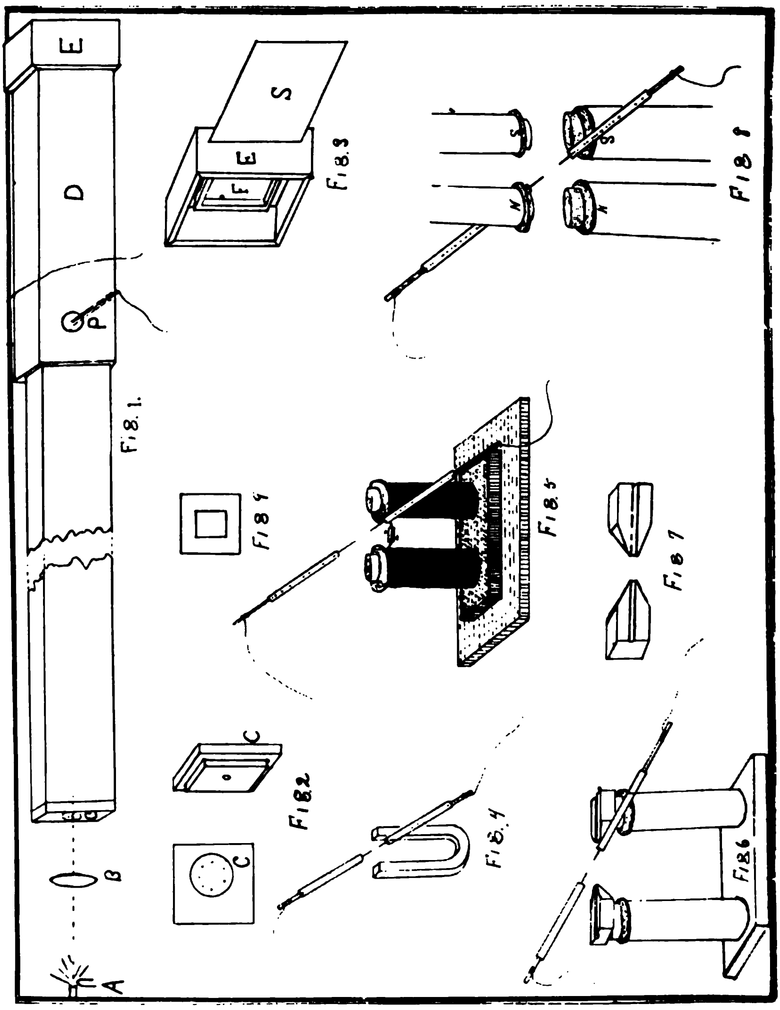


Fig. 1.
Fig. 2
Fig. 3
Fig. 4
Fig. 5
Fig. 6
Fig. 7
Fig. 8
A
B
C
D
E
P
S

diameter and 5.2 cm. long. They were soldered into the ends of brass rods 0.5 cm. in diameter. The rods were placed in glass tubes and held firm by sealing wax at the two ends of the tubes. The points were charged by means of a four-mica-plate Wagner static machine (the Leyden jars had been removed), which was run by an electric motor with a rheostat in circuit for regulating the speed. The rods extended through the sides of the camera as shown by (P) Fig. 1, so that the points were near its axis. The points were about 15.5 mm. apart for the first three series of photographs and about 17 mm. apart for the last four series.

For the first series of photographs the magnet extended through the lower side of the tube directly below the points and was placed so that the tops of the pole pieces were about 0.5 cm. below the points. When the separable pole pieces, Fig. 7, were used they were covered with a layer of sealing wax about 3 mm. thick on all sides except the one facing the magnet cores, to prevent sparks passing to the magnet from the points.

As a preparation for the experiment the simpler part of Precht's work was repeated (i. e., apparatus was set up containing one point and one blunt electrode in the same position shown by the points in Fig. 6). The deflection of spark, brush and glow discharge were easily observed in a semi-darkened room when a transverse field was produced by exciting the magnets. Some cases were observed in which the discharge was transformed from one type into another, but no measurements were made of the potential, nor determination made of the signs of the charge on the points to see if they accorded with the results given by Precht.

The magnets and points were then placed in the tube as described and photographic records made of the discharge. The silent discharge was first studied. To produce the magnetic field a permanent horseshoe magnet was first used, and although it was strong enough to blow out the arc of an arc lamp, the photographs taken showed no deflection of the stream. It was then replaced by an electro-magnet, Fig. 5, later pole pieces, Fig. 7, were placed as shown in Fig. 6, and finally two electro-magnets placed in opposition, Fig. 8, in attempts to produce a field sufficiently strong to deflect the stream. The magnets were weak compared with those used by Precht and H. E. Schaeffer. The field measured only about 1,000 gausses as used in Figs. 5 and 6, and only about 1,500 gausses as used in Fig. 8. None of the photographs taken of the silent discharge showed any deflection when the magnets were excited.

Seven series of photographs were then taken.

A—Is a visible spark discharge.

B—Is a Brush discharge (a violent stream extended about 0.8 cm. from the positive point. The negative point showed only a bright speck).

C—The glow or silent discharge. (Nothing was visible between the points in the darkened tube. Each point showed a bright speck.)

D—Spark discharge representing the highest speed of the machine and highest potential between the points.

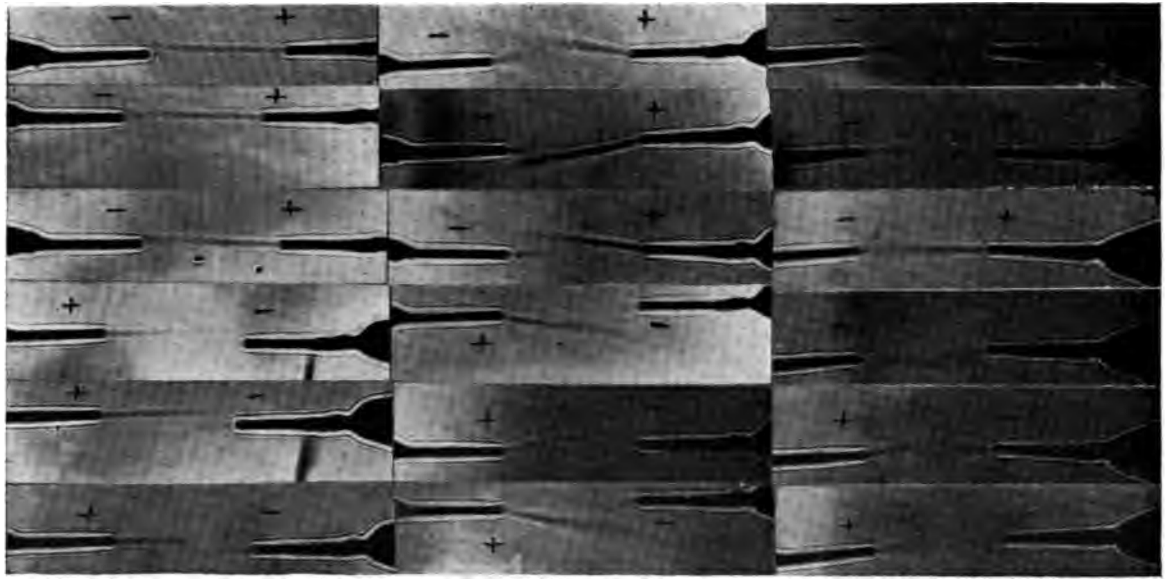
E—Spark discharge, representing the lowest speed of the machine at which a visible spark passed between the points. A lower speed would have caused the spark to change to brush.

F—Silent discharge, same as C.

G—Silent discharge, same as C. Deflected by a stream of air issuing from below the points.

The different series in decreasing order of their potential as represented by the relative speed of the machine are D, A, E, B (C, F or G). Series A, B and C were taken with magnet and pole pieces as represented in Fig. 6. The magnetic field strength was about 1,000 lines per sq. cm. in the region of the points. The points were 15.7 mm. apart. Series D, E and F were taken with the magnets as shown in Fig. 8. The magnetic field strength in the neighborhood of the points was about 1,500 lines per sq. cm.

The six numbers of each series, A, B, C, D, E and F, were taken in succession as rapidly as possible, it requiring 20 or 30 minutes to complete the series. In the photograph the longer stream is the one from the positive terminal and the shorter one the stream from the negative electrode. If the positive stream is from right to left it is designated as "first direction," if from left to right, as "second direction." Nos. 1, 2 and 3 then show current in the "first direction," while Nos. 4, 5 and 6 show current in the "second direction." If the magnets were excited so that the direction of the lines of force were from the front to the back of the photograph (i. e., after correcting for the reversal in direction caused by printing from the plate), the direction of magnetism is designated as "first direction," and those with the lines of force from back to front of the page are designated as magnetized in the "second direction."




D E F

No. 1. Current first direction; magnetism (none).
No. 2. " " " " 1st direction.
No. 3. " " " " 2d "

No. 4. Current second direction; magnetism (none).
No. 5. " " " " 1st direction.
No. 6. " " " " 2d "

Following then this plan, Nos. 1 and 4 show the current when the magnets are not excited. Nos. 2 and 5 show the current in a field of the "first direction," and Nos. 3 and 6 show it in a field of the "second direction." It may be observed from the photographs that the streams in series A, B, D and E are deflected as if they were flexible conductors bearing a current, in so far as direction of deflection is concerned, thus indicating that the stream is one of charged particles.

But some characteristics of the photographed stream are hard to explain on the theory that the air is ionized and that the stream consists of charged particles. The glow discharge and the negative stream in all cases show no deflection in a field of 1,500 gausses. Also the stream goes in a straight line after leaving the point instead of following a curved path to the opposite electrode, and there seems to be no connection or joining of the negative and positive streams. In some ways it acts as the air and vapor streams investigated by Professor Foley and Mr. Haseman. In case of the silent discharge, where the machine was run at its lowest possible speed and the potential was the lowest, the stream retains the same size as far as it can be traced. In series B there is not much change in the width of the stream. Series E shows the stream growing broader as the distance increases from the electrode. Series A shows a still greater broadening and D an even greater dispersion. The greater pressure in the stream no doubt accompanies the greater potential difference, and therefore accompanies the greater dispersion of the stream, as was shown to be true in case of air and vapor streams by Professor Foley and Mr. Haseman. Series E and B show a greater deflection than any other series, and since B was the highest potential brush discharge and E the lowest potential spark discharge which could be obtained without a transformation of the type of discharge, these few photographs indicate that the greatest magnetic deflection is produced when the discharge is on the verge of changing from one type into the other. Enough photographs were not taken to verify this, however.

It will be observed in Nos. 1 and 4 of the series E that the stream does not always pass along a line directly between the points, even when the discharge takes place outside a magnetic field. In the observations made such cases were in a minority, the discharge as a rule passing directly between the points or nearly so. The cause of its deviation in these few cases was not learned.

Also, very often when adjusting the speed to obtain photographs for series B and E the discharge would change from one type to the other when the magnets were excited. Precht found that this was the case, but these observations can hardly be compared with his, since point electrodes were used in this case, while he used one point and one blunt electrode. In all cases observed where a change occurred, if a brush discharge in a nonmagnetic field passed above or below a line directly between the points as shown by the spark discharge E, 1 and 4, and the magnets were excited to deflect the stream in such a way as to make the path of discharge shorter, it changed to a spark discharge. Or if a spark discharge passed directly between the points and was deflected it changed to a brush. In all observed cases (possibly 25 or 30) the transformation could be explained by the change of distance.

The series G shows the effect of an air current on the path of discharge. The air current was led into the camera through the bottom side by means of a glass tube 2.25 cm. in diameter so that the mouth of the glass tube was 2.2 cm. below the points, and flowed at the rate of about 1,200 c. c. per second. Nos. 1 and 3 show the discharge without the air current, and Nos. 2 and 4 show deflection by the air current. It differs from the deflection produced by the magnetic field in that the greater deflection here is with the negative stream. This indicates that the pressure is not as great in the negative stream as in the positive, which agrees with the work of [1]S. Arrhenius, who measured the torsion produced by a suspended wire cross with points bent at right angles to point in the same direction and found that the torsion produced by the negatively charged wire was less than the positively charged wire, which was more clearly shown the lower the potential. (Note—It was intended to show a photograph with current in second direction, deflected by an air current. G 4, which should have shown this, shows a current in the same direction as G 2, which was due to a reversal of polarity of the machine. The error was not observed until the apparatus was torn down.)

Series H shows photographs of the points when the poles of the machine were placed close enough for a spark to pass between them. It was found that when a spark passed between the poles of the machine there was a violet stream (brush) between the points. This violet stream did not usually pass directly from one point to the other, but was curved with

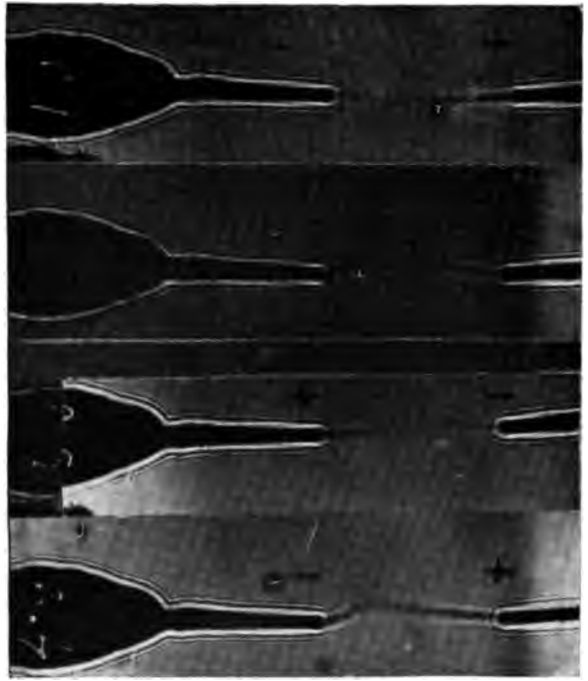
[1] S. Arrhenius (Annal. Phys. Chem. 63, pp. 305-313), 1897.

No. 1.

No. 2.

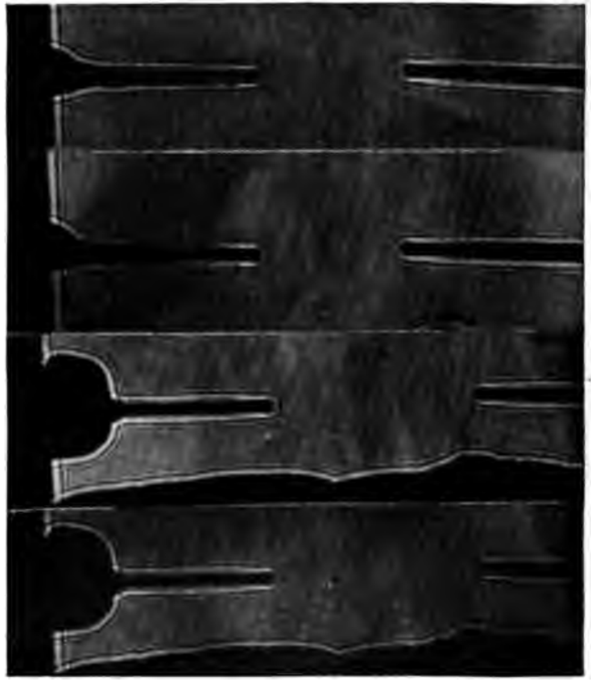
No. 3.

No. 4.



G

Nos. (1 and 3) G. Without air stream.
Nos. (2 and 4) G. With " "



H

H. Spark between poles of the machine, violet brush between points.

the two ends connected to the needles, not always at the points. When the magnets were excited there was no deflection observed in a field of 1,500 gausses. The photographs taken show nothing between the points.

Before putting on the cap containing the plate to take the photographs in series D a pencil drawing was made of the general form of each spark as seen from the end of the tube. Fig. 10 is a blue-print taken from these drawings, which shows that the direction of the spark as it leaves the electrode has the same direction as the photographed stream.

The width of the streams was measured in the proximity of the point with a micrometer microscope, and it was found that the width was independent of the potential between the points. The measurement was made between the outer edges of the central dark band. It will also be noticed in series D that the negative stream is almost as plain and almost as long as the positive stream.

The photographs of series E show plainly the interference fringes as described by Professor Foley. Although no special pains were taken to show these fringes in any of the work, one or two can be seen on each photograph.

## SUMMARY OF RESULTS.

1. The positive stream between the points for a spark or brush discharge was deflected by a magnetic field as low as 1,000 gausses, the direction of deflection being in accordance with electro-dynamic laws.

2. The stream for glow discharge and the negative stream in any case were not deflected by a field of 1,500 gausses.

3. The direction of the photographed stream for a spark discharge as it leaves the point is the same as the visible direction of the spark.

4. The size of the stream at the points is independent of the potential between the points.

5. The stream was deflected by an air current, the negative being deflected more than the positive.

6. The stream for the high potential spark increased in width as the distance from the point increased, while the stream for the glow discharge retained its original size as far as it could be traced.

7. Some of the data indicate that the stream photographed is one of the ionized air particles, the stream as a whole having an index of refraction different from that of the surrounding air, due to its pressure.

If this is the case, however, the silent discharge stream and the negative stream should have been deflected also. This might possibly be done with a stronger field. Also, the stream, if it consists of charged particles, should terminate on the opposite electrode, which is very seldom the case.

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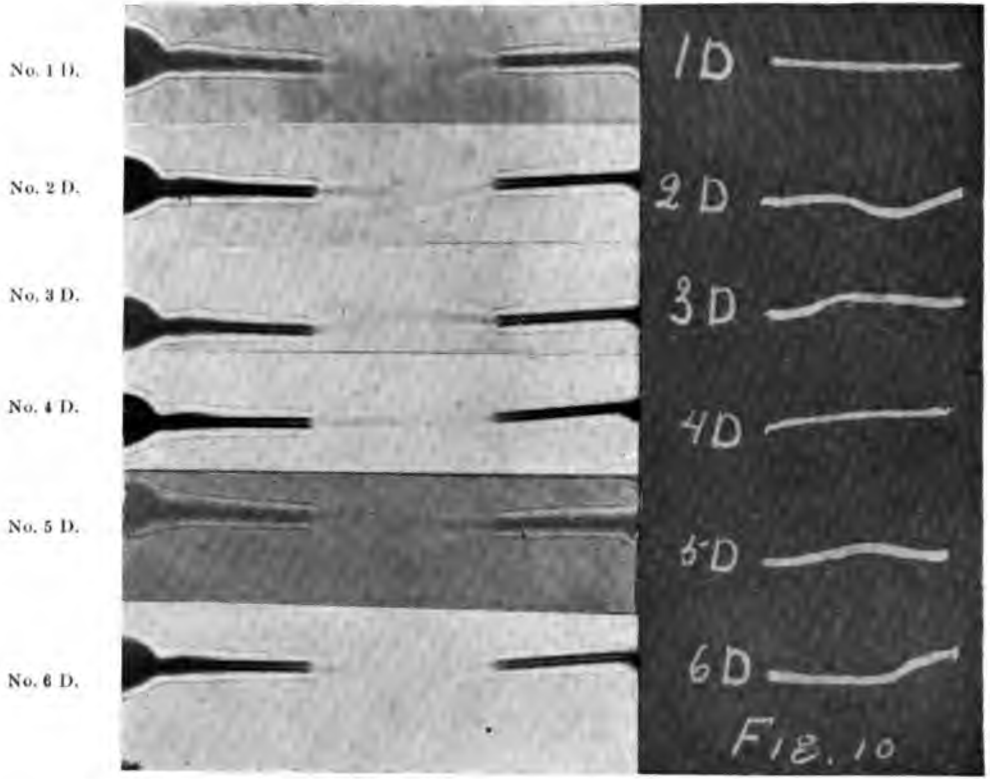
The above investigation was suggested by Professor Arthur L. Foley of Indiana University. I wish to thank him and Professor R. R. Ramsey for their helpful suggestions during the course of the investigation.

Physics Laboratory of Indiana University.
Bloomington, Ind.


No. 1 D.
No. 2 D.
No. 3 D.
No. 4 D.
No. 5 D.
No. 6 D.
1 D
2 D
3 D
4 D
5 D
6 D
Fig. 10

# The Tenacity of Gelatine.

[Publication No. 35.]

By Arthur L. Foley.

Some years ago the author called attention to the fact that the cohesive forces of gelatine must be considerably greater than those of glass in order that a single drop of gelatine in drying and contracting on a glass plate may pull a ring or disk of glass from the plate.[1] The forces here exhibited are apparently greater than shown in the common, though not well known, process of producing chipped glass by flowing a pane of glass with gelatine and allowing the gelatine to dry. Inasmuch as the author could not find in any of the literature at hand any recorded values of the tensile strength of gelatine, he requested one of his students to attempt to determine its value. Several plans were tried, the one giving the best results being as follows:

Gelatine threads were drawn out between the ends of small wooden sticks (about the size of a match) after dipping one end of each in melted gelatine. The diameter of a thread was varied by varying the size and temperature of the gelatine drop, the thickness of the fluid, the length of the thread and the time spent in drawing it. To the other end of the wooden sticks there had been attached previously small wire hooks for suspending the upper end of the threads and for attaching a small cloth sack to the lower end. Into this sack dust shot were slowly run until the thread broke. The cross-section of the thread was then measured at the point of break.

When the section of a thread was regular its cross-section was calculated from the diameters measured by a micrometer microscope. Threads of irregular cross-section were placed under a microscope with a camera lucida attachment and a tracing made of the perimeter. The area of the tracing was measured with a planimeter and the area of the section of the thread itself calculated from the known magnifying power of the microscope and attachment.

When glass threads are drawn they are usually almost cylindrical. Gelatine threads also are probably approximately cylindrical at the time

[1] Note on the Molecular Forces in Gelatine. Science, Vol. 23, p. 790, May 18, 1906.

of drawing, but they are not so after hardening and drying. The cross-section usually becomes quite irregular. This indicates a condition of internal strain which acts to lower the breaking strength of the thread. Coarse threads would be subject to greater strains than fine threads, and therefore we should expect them to show a smaller tensile strength than the fine threads. This is in accord with the results of experiment as shown by the data of Table I.

TABLE I.

| Cross Section in sq. mm. | Breaking Strength in grams. | Tensile Strength in Kgm. per sq. cm. |
|---|---|---|
| .000835 | 27.6 | 3,305 |
| .000919 | 21.5 | 2,340 |
| .001002 | 21.1 | 2,106 |
| .001334 | 37.2 | 2,778 |
| .001670 | 35.0 | 2,096 |
| .002610 | 58.2 | 2,230 |
| .004524 | 96.5 | 2,133 |
| .006729 | 138.1 | 2,052 |
| .013920 | 211.4 | 1,519 |
| .035900 | 400.1 | 1,114 |
| .130300 | 800.0 | 614 |
| .264900 | 2,850.0 | 1,076 |
| .608900 | 5,600.0 | 919 |
| 1.709200 | 6,100.0 | 357 |

Inasmuch as the error in measuring the breaking strength of any particular thread was relatively small and all strains tended to decrease that strength as measured, I have included in Table I only maximum readings; that is, readings which gave the greatest values of the tensile strength for the several sizes of threads. Average readings gave results some twenty per cent lower.

Curve A of Fig. 1 is a plot of some of the individual maximum readings of Table I. It will be observed that the measured tensile strength increases very rapidly as the threads are made thinner. A similar increase takes place in wires and glass threads, and is attributed to a "skin effect." This increase is shown in Curve B, Fig. 1, which represents the results ob-

tained by drawing out glass threads and determining their tensile strength by the method already described. That the increase in the case of glass threads was due in part only to the "skin effect" was indicated by the fact that the tensile strength measurements for threads of different sizes were made more nearly uniform by carefully annealing the threads. This was done by hanging the threads in a vertical iron tube with a small weight attached to the lower end of each thread to keep it straight. The entire tube was then brought to a temperature slightly below the melting point of glass and maintained at that temperature for one hour, after which it was allowed to cool slowly in the asbestos jacket surrounding it.

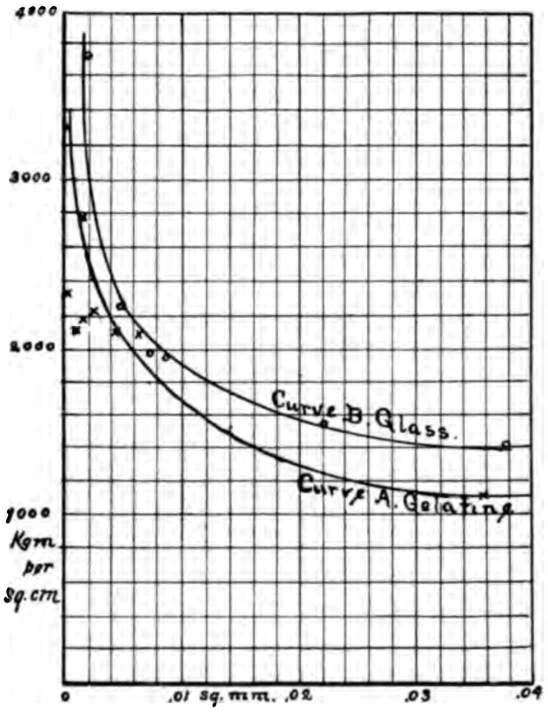



Fig. 1.

An attempt was made to anneal the gelatine threads by hanging them in a moist atmosphere in an enameling oven. Various oven temperatures were tried with little permanent effect on the threads. The author inclines to the view that the "skin effect" does not account for the larger values of the tensile strength shown by the finer gelatine threads, but that it is due chiefly to the cause already suggested—the greater uniformity in the finer threads.

The highest value of the tensile strength obtained for glass threads was 3,652 kilograms per square centimeter, while the maximum for gelatine threads was 3,265 kilograms per square centimeter. It is evident that these values cannot represent the true values or the relative values of the tenacity of glass and gelatine. It may be that the internal strains set up in the gelatine threads were such that the tensile strengths as determined in this experiment were always too low. Or it may be that the "skin effect" in glass threads gave values far beyond the tenacity of glass in a plate. Further experiments along this line are in progress.

The strength of the gelatine threads was found to increase for a few hours after drawing, and then to decrease—especially when the thread was exposed for a day or two to a dry atmosphere. Impurities tended to weaken the threads. Curve A of Fig. 2 showing the tensile strength of threads of ordinary glue, Curve B those of gelatine containing six per cent of potassium chlorate, and Curve C those of supposedly pure gelatine. Gelatine containing six per cent of potassium alum gave a curve similar to Curve B; that is, the tensile strength of the gelatine was diminished by the salt. Still it must be greater than the tenacity of the glass, for in chipping glass about six per cent of some easily crystallizable salt is mixed with the glue in order to produce the peculiar fern-

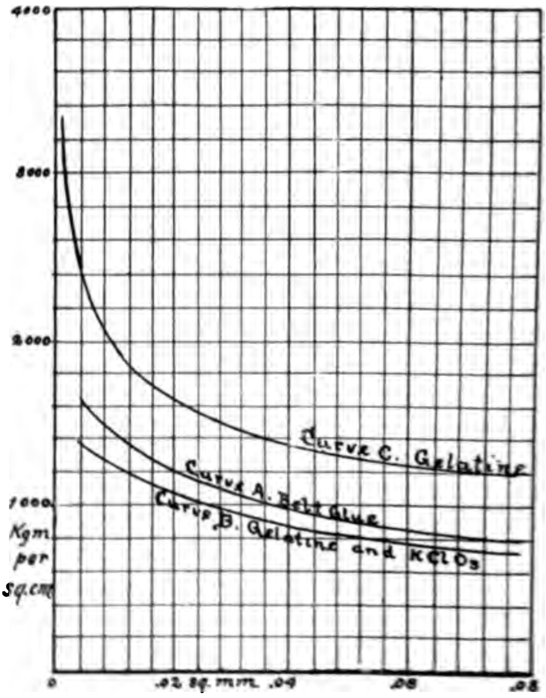



Fig. 2.

like forms which give chipped glass its decorative effect. Evidently there are forces involved here other than cohesion and adhesion, as these terms are commonly used.

Most of the experimental work of this investigation was done by Mr. Elmer J. Harrel, now of the high school of St. Paul, Minn.

Physics Laboratory of Indiana University.
Bloomington, Ind

# Effect of Certain Dissolved Salts Upon the Cohesion of Water.

By Edwin Morrison.

Cohesion is defined as "that force which holds molecules of the same kind together." This force is very manifest in all solids, giving rise to such properties as hardness, brittleness, malleability, ductility, tensile strength, etc. Although not so apparent, all liquids manifest the same kind of an attractive force between molecules. Surface tension and the phenomenon of capillarity are due in a measure to cohesion of the molecules. That molecules of water are held together by means of cohesion can be demonstrated by bringing a clean, horizontal disk of glass in contact with the surface of water and then adding sufficient force to pull the disk away from the water. In case the surface of the disk is wet when it comes away from the water we know that the force applied has separated two films of water, each equal in area to that of the disk.

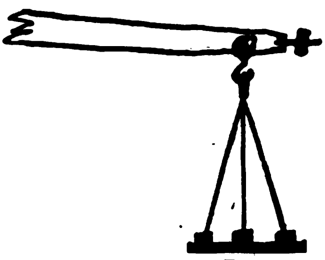


Fig. 1.

Probably Gay-Lussac first experimented upon this force and established the commonly accepted data of 526.875 dynes per square cm. Gay-Lussac used a glass disk supported by three guy cords as shown in Fig. 1.

The author designed and constructed a piece of apparatus for measuring cohesion of water and other liquids and reported the same to the Iowa Academy of Science in 1904. This apparatus consists of a round glass disk 10.6898 cm. in diameter mounted upon an accurately constructed cone 10.5 cm. high, with an eyelet in the apex for suspending the cone from the hook of a specific gravity balance. A cut of this apparatus is shown in Fig. 2.

In 1905 the author carefully worked out and reported to the Iowa Academy of Science the value of the cohesion of water as follows:

**Data.**—Diameter of the glass disk.

| | |
|---|---|
| 1 Measurement | 10.662 cm. |
| 2 Measurement | 10.698 cm. |
| 3 Measurement | 10.727 cm. |
| 4 Measurement | 10.694 cm. |
| 5 Measurement | 10.645 cm. |
| 6 Measurement | 10.674 cm. |
| 7 Measurement | 10.702 cm. |
| Average | 10.6898 cm. |

Fig. 2.

Test No. 1.—The number of grams to separate the disk from water at 4° C.

| | |
|---|---|
| Trial 1 | 48.725 |
| Trial 2 | 48.730 |
| Trial 3 | 48.725 |
| Trial 4 | 48.733 |
| Average | 48.728 |

Test No. 2.—The number of grams to separate the disk from water at 7° C.

| | |
|---|---|
| Trial 1 | 48.710 |
| Trial 2 | 48.715 |
| Trial 3 | 48.725 |
| Trial 4 | 48.730 |
| Average | 48.720 |

Test No. 3.—The number of grams to separate the disk from water at 7° C.

| | |
|---|---|
| Trial 1 | 48.630 |
| Trial 2 | 48.640 |
| Trial 3 | 48.655 |
| Trial 4 | 48.675 |
| Average | 48.650 |

The diameter of the disk being 10.6898 cm., the radius being 5.3449 cm., the area is 89.7200 square cm. In the first test given above it required 0.5431 g. to separate one square cm. of water. In the second 0.5430 g. and in the third 0.5421 g. The average of the three tests is 0.5427 g. per square cm., which is equal to 531.846 dynes per square cm.

In comparing these results with those of Gay-Lussac we find that he used a disk which was 11.86 cm. in diameter, and that it required 49.40 g. to separate the disk from water, or 526.875 dynes per square cm.

At this point it may be well to state the precautions taken in the experiment. First, in order to insure that the water used was chemically pure, ordinary laboratory distilled water was redistilled in Jena glass vessels in the presence of sulphuric acid and potassium dichromate. Second, the disk was thoroughly cleansed by washing in a solution of potassium dichromate and sulphuric acid; then in alcohol; then the disk was dried in a current of air and washed again in redistilled water. Third, a delicate laboratory balance with a rider weight was used in the experiment.

At the time the above data on the cohesion of water was worked out it was suggested that certain dissolved salts have a marked effect upon the cohesion of water. It is the purpose now to note some of these effects.

A number of solutions of certain salts in distilled water have been tested by means of the same glass disk as used in the cohesion of water experiment. The first solution tested was that of sodium chloride. Six

solutions were prepared by dissolving each of the following number of grams of salt in 200 cc. of distilled water: 7.82 g., 15.64 g., 31.28 g., 46.92 g., 62.56 g., 72 g. (saturated solution).

Six solutions each of copper sulphate and sugar were prepared in the same way as in the case of sodium chloride, and each solution was tested for the number of grams to separate the liquid films.

The results for the eighteen different solutions are tabulated as follows:

First.—The number of grams to separate the disk from the solutions when 7.82 g. of each of the three materials were dissolved in 200 cc. of water.

| Trial. | Sodium Chloride. | Copper Sulphate. | Sugar. |
|---|---|---|---|
| 1 | 42.45 | 48.40 | 48.50 |
| 2 | 42.50 | 48.45 | 48.52 |
| 3 | 42.50 | 48.47 | 48.48 |
| Mean. | 42.48 | 48.44 | 48.50 |

Second.—The number of grams to separate the disk from the solution when 15.64 g. of each of the three materials were dissolved in 200 cc. of water.

| Trial. | Sodium Chloride. | Copper Sulphate. | Sugar. |
|---|---|---|---|
| 1 | 42.15 | 49.20 | 50.50 |
| 2 | 42.00 | 49.30 | 50.52 |
| 3 | 41.95 | 49.35 | 50.51 |
| Mean. | 42.03 | 49.28 | 50.51 |

Third.—The number of grams to separate the disk from the solutions when 31.28 g. of each of the three materials were dissolved in 200 cc. of water.

| Trial. | Sodium Chloride. | Copper Sulphate. | Sugar. |
|---|---|---|---|
| 1 | 46.39 | 50.35 | 51.50 |
| 2 | 46.30 | 50.37 | 57.49 |
| 3 | ............ | 50.35 | 51.51 |
| Mean. | 46.345 | 50.356 | 51.50 |

Fourth.—The number of grams to separate the disk from the solutions when 46.92 g. of each of the three materials were dissolved in 200 cc. of water.

| Trial. | Sodium Chloride. | Copper Sulphate. | Sugar. |
|---|---|---|---|
| 1 | 50.00 | 51.00 | 53.10 |
| 2 | 50.02 | 51.05 | 53.10 |
| 3 | 50.01 | 51.07 | 53.50 |
| Mean. | 50.01 | 51.06 | 53.26 |

Fifth.—The number of grams to separate the disk from the solutions when 62.56 g. of each of the three materials were dissolved in 200 cc. of water.

| Trial. | Sodium Chloride. | Copper Sulphate. | Sugar. |
|---|---|---|---|
| 1 | 50.90 | 51.50 | 55.70 |
| 2 | 50.85 | 51.45 | 55.80 |
| 3 | 51.05 | 51.25 | 55.75 |
| Mean. | 50.90 | 51.46 | 55.75 |

NOTE. The copper sulphate solution was a saturated solution.

Sixth.—The number of grams to separate the disk from the solutions when each of the three materials were saturated solutions at the normal temperature.

| Trial. | Sodium Chloride. | Copper Sulphate. | Sugar. |
|---|---|---|---|
| 1 | 50.92 | .............. | 57.00 |
| 2 | 51.05 | .............. | 56.95 |
| 3 | 50.90 | .............. | 57.10 |
| Mean. | 50.96 | 51.46 | 56.99 |

These results for each of the three dissolved salts may be plotted graphically by using the number of grams concentration as abscissas and grams to separate the disk as ordinates.

CONCLUSIONS.—First, the above data seem to indicate that within certain limits the cohesion of water with dissolved salts in it is a function of the concentration.

Second, as far as tested all dilute solutions of salts in water render the cohesion of the solution less than that of pure water.

Third, so far as tested the dilute strongly basic salts produce a greater decrease in the cohesion of the solution from that of pure water than the nonbasic salts.

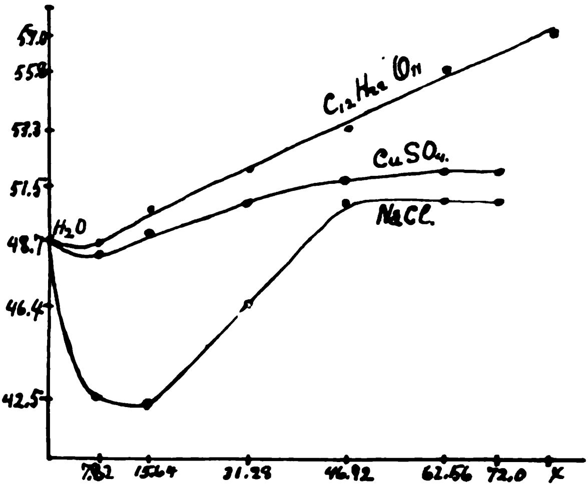



Fig. 3.

Fourth, it is also noted that before the point of saturation is reached in the strongly basic solutions, increased concentration does not produce increased cohesion.

Tests are in progress with various other salts than the ones referred to above. Also tests are in progress in which other solvents than water are being used.

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# Some Features of Delta Formation.

By Charles R. Dryer.

In August and September, 1902, the writer spent some weeks among the western Finger lakes in Livingston and Ontario counties, New York. Along the shores of Hemlock Lake his attention was attracted by many recently formed deltas which seemed to present unusual features. Each delta was a semi-circular pile of fine shale shingle symmetrically arranged around the mouth of a little gully formed by a wet weather stream. The level top stood about two feet above the lake surface and was bounded by a bank of shale which sloped downward about three feet in six to a mud line under water. The wash of waves had cut at the top of the slope a vertical cliff six inches high. The land side was bounded by a very steep bank of stratified shale, a portion of the general lake shore, which is almost everywhere precipitous. From the mouth of the gully a groove a foot wide and six inches deep extended straight out half way or more across the top of the delta, but in no case reached the water's edge. Along the sides of the groove lay sticks of wood and fragments of shale of relatively large size. One medium sized delta measured thirty-one feet by twenty-six in diameter. No camera was at hand, but sketches were made from which a rough model was constructed and photographed. (Fig. 1.)

Fig. 1. Model of Torrential Delta in Shale Gravel.

The interpretation of the phenomena seemed plain. These deltas were built during an exceptionally violent storm which filled the gully with a rushing torrent and raised the level of the lake. The force of the stream was abruptly checked at lake level and its load was deposited in the form of a fan-like delta. Toward the last of the storm the stream striking the

flat top of the delta dug out the groove for a few feet, but was deflected upward and spread out into a thin sheet before reaching the edge. This interpretation was confirmed by the records of rainfall and lake level kept by the Rochester water works at the foot of the lake, which is the source of public supply for that city. These records are as follows:

| *Date.* | *Hours.* | *Rainfall.* | *Lake Level Above Datum.* |
|---|---|---|---|
| July 5 | 12:30–7:00 p. m. | .921 in. | 1.736 ft. |
| " 6 | In the night. | 2.349 " | 2.926 " |
| " 7 | 10:00–11:00 p. m. | .546 " | 3.106 " |
| " 8 | ............... | ........ | 3.126 " |
| " 18 | 8:00–11:00 a. m. | .101 " | 2.176 " |
| " 19 | In the night. | 1.397 " | 2.296 " |
| ........ | 2:00–6:00 p. m. | .607 " | ........ |
| " 20 | In the night. | .864 " | 2.546 " |
| " 22 | ............... | ........ | 3.186 " |

These deltas were begun during the heavy rains of July 5-7, when 3.816 inches of rain fell and the lake rose 1.39 feet, most of the work being done in the night of July 6, when 2.35 inches of rain fell. They were completed July 18-20, when 2.97 inches of rain fell and the lake rose 1.01 feet. These miniature torrential deltas furnish suggestions for the interpretation of similar but larger features which mark the shore lines of the temporary glacial lakes formerly occupying the Finger lake valleys.

A similar flat-topped, steep-sided feature caught the writer's eye on the east side of Honeoye Lake. Projecting from the steep hillside like a bracket it rose 200 feet above the lake, suggesting by its bold and symmetrical outlines an artificial origin similar to that of the dump pile of a mine (Fig. 2). It proved to be a torrential delta built at the mouth of Briggs gull. Its finely curved front slope, about 150 high, is as steep as the material will lie. Its flat top is traversed by a channel twenty feet wide and three feet deep which extends to the edge and is continued by a similar groove in the steep face. The southern side cut away by the main stream shows characteristic foreset beds of sand containing large fragments of shale near the top. Briggs gull now drains a basin of about six square miles. A heavy rain with rapid melting of ice or a sudden diversion of drainage by the breaking of an ice dam in glacial times may have enabled the stream to build this delta in a few days or weeks. Briggs delta helps to account for the anomalous distribution of glacial lake deltas. Similar features are numerous in the Finger lake valleys. Not their presence but their absence from the former mouths of many streams seems

ıief problem. Why do not deltas occur on all of the hundreds of ıs that score the valley sides? Why did one stream a mile or two uild a delta a few rods in area while a much longer stream near by

A.

B.

Fig. 2. Briggs Delta. A. From below. B. From above.

one? The answer seems to be that such features have no prolonged ', but owe their existence to a single local and brief accident of ge which did not affect neighboring streams.

by the occurrence upon the highest level of a sharp kettle hole 300 feet in diameter and 25 feet deep, marking the place where a detached ice block stranded and melted.

The occurrence of kettle holes in deltas is not uncommon.[1] A remarkable case of this kind has been described by the writer where an area of ten acres of delta surface is thickly pitted with small kettles.[2] (Fig. 4.) This delta is the joint product of a land stream and a valley glacier which contributed ice blocks and an undetermined portion of the permanent material. There are probably many intermediate forms between such a *morainal delta* and one due wholly to stream work.

**Fig. 5. Outer Face of Morainal Delta. Fan in front of notch.**

When lake waters are withdrawn the bisection of a delta may result in the formation of an alluvial fan in front of it. This gives a characteristic combination of *notched delta and fan.* (Fig. 5). The fan of Mill Creek at the foot of Honeoye Lake is a mile in diameter, and is responsible for the existence of the lake, to which it acts as a dam. The fan of Canadice outlet bears a similar relation to Hemlock Lake, which, however, is too deep to owe its existence wholly to that cause.

Deltas occasionally take the form of long, narrow ridges upon one or both sides of a stream, resembling the natural levees in "the goosefoot"

[1] Fairchild, Journal of Geology, Vol. 6, p. 589.
[2] Bulletin Geological Society of America, Vol. 15, p. 457.

of the Mississippi. Normally the point where a tributary valley joins a larger one is marked by a notch in the wall of the latter, but in some cases a bisected spur appears instead. The delta of Canadice outlet, mentioned above, furnishes a good example. A delta at Lake Warren level, near East Bloomfield, what is left of it, has the form of a single narrow tongue more than a half mile long. Such lateral deposits of a stream may be called *levee deltas.*

Hanging deltas have been the chief guides to geologists in mapping the outline of temporary glacial lakes, but they are worthy of more careful study as simple and well displayed specimens of constructional shore forms.[3]

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[3] Nearly all the features mentioned in this paper may be found upon the Wayland, Naples, Honeoye and Canandaigua sheets of the Topographic Map of United States.

# A Physiographic Survey of an Area Near Terre Haute, Indiana.

By Chas. R. Dryer and Melvin K. Davis.

*The Survey.*—In the summer of 1909 the senior author of this paper, in despair of living long enough to receive any help from the U. S. Geological Survey or from the State of Indiana, resolved to try what might be done by his own students toward a serviceable topographic survey of the area around Terre Haute. Four young men and two young women were ambitious enough to undertake the work. For a base map the atlas of Vigo county was used and found to be very poor, in fact a disgrace to the surveyor, the draughtsman, the printer and the whole community concerned. We simply made the best of it. The profiles of three railroad lines traversing the region were obtained, and other base lines and points were determined with a surveyor's level. Most of the topographic work was done with the hand level and staff. It was found possible to require that no discrepancy between different lines of levels should exceed one foot. Highways and divides were followed and section and other cross-country lines were run wherever necessary. About two days a week for six weeks were spent in the field, and the result was found to be worth while. While surveying was being done the location of particular features was noted in order that no time would be lost when their special study should come. The map drawn by the junior author of this paper from the data thus secured has proved adequate for the purpose in view.

*General Description.*—The area surveyed is immediately west of Terre Haute and comprises about 25 square miles in Sugar Creek township, Vigo county, Indiana. It is bounded on the east by the Wabash river and includes a portion of its flood plain. West of the Wabash bluffs, here eighty to one hundred feet high, the area consists of an originally smooth upland of glacial drift 540 to 560 feet above sea level, which has been submaturely dissected by the branches of Sugar creek. The remnants of the original surface have been reduced to the scrap-tin outline characteristic of the leaves of the pin oak. The larger valleys are flat bottomed and contain alluvial filling to a depth of 40 or more feet. The drilling of a well at Vandalia mine No. 81, section 24, showed the deposit to be 40 feet

deep. The slopes of valley sides are generally steep and the ravines of the ultimate tributaries are exceedingly narrow and sharp. The depth of the glacial drift is generally from 40 to 60 feet, and the streams only here and there touch bed rock.

Many beds of recent conglomerate appear along west Little Sugar creek. The principal valleys are preglacial, with a base level determined by the level of the preglacial Wabash, which was 60 or 70 feet lower than the present river. These valleys were filled with drift which the post-glacial streams have scarcely half removed. The drainage has developed by headward erosion into an intricate, dendritic system of insequent branches which penetrate to nearly every acre of the area. Judging from the position of large trees there is reason to believe that the lines of drainage were well defined before vegetation sprang up.

*Stratigraphy.*—The underlying bed rocks of the area are the shales of the coal measures with several workable seams of coal, the uppermost of which outcrops along the foot of the Wabash bluffs. The shales above the coal form about one-half the height of the bluffs. The upper half consists of glacial drift. Intercalated with the shales are several thin strata of limestone, two of which exercise a notable influence upon the topography. Below the 500-foot level a tough, flinty limestone four or five feet thick has resisted river erosion to such an extent as to form a terrace between the Wabash flood plain and bluff, in some places 500 feet wide and 20 feet above the plain. We call it the flinty limestone. A similar but less silicious limestone lies about thirty feet higher. In section 31 the waters of the Sugar creek system have cut a gap in these strata and reach the Wabash at grade.

The glacial drift belongs to the Illinoian drift sheet of Leverett and lies just outside the border of the Shelbyville moraine. The mass of it consists of a tough boulder clay, weathering on exposed faces into roughly hexagonal columns and containing numerous striated and faceted boulders of moderate size. Large boulders are rare. In some places the till is one-half fine gravel. There are occasional thin partings of sand. In a railroad cut about one mile to the north of the area surveyed buried logs of wood up to nine inches in diameter are numerous along a level horizon, but no difference can be discovered between the overlying and the underlying till. In the south bluff of Sugar creek beds of laminated silt are intercalated in the till and point to the occurrence of an interglacial interval of notable extent. The upper four or five feet of drift often con-

sist of a deep red, pebbleless and structureless loam, the origin of which is an unsolved problem. The red loam, even upon moderate slopes, gullies rapidly and has greatly facilitated the dissection of the region.

*The Wabash Plain*, two miles in width, presents the usual flood plain features of levees and bayous. At one point, S. W. ¼ of S. E. ¼ of section 8, shale outcrops in the midst of the alluvium. Before the valley was filled this was an island in the river with deep water all around it. The valley filling in some places is 80 feet deep, and consists of sand and gravel carried into the valley by water and floating ice. At a railroad gravel pit in section 36 twenty-five feet of fine gravel is exposed, with an occasional stratum containing enough clay to resist rain wash and cause the formation of earth pillars two or three feet high. A terrace of coarse, roughly stratified gravel formerly occupied an area about one mile by one-half opposite the city of Terre Haute and was an island at high water. The town of West Terre Haute stands upon the southern half of it. The northern half has been entirely removed by the railroad companies and excavated to the level of low water in the river. The remaining surface is from 15 to 25 feet above the plain.

*The Sugar Creek Drainage System* presents several peculiar features and furnishes some of the most interesting problems of the area. The small tributaries of the Wabash are usually of the parallel type, not combining into systems, the main streams flowing nearly at right angles to the Wabash. The Sugar creek system is fan-shaped, consisting of four principal streams which converge southward and eastward to a junction and pass out through a single gap upon the Wabash plain. East Little Sugar creek flows southward seven miles parallel with the Wabash river and about one mile west of the bluff. In sections 25 and 26 a nameless stream flows about one mile eastward, turns northward one-half mile and again eastward, both bends being right angles. This seems to be due to harder material in the stream's course.

*Sugar Creek Lake.*—At the western border of the area surveyed the valley of Sugar creek widens abruptly from less than one-half mile to about a mile. Two miles below it narrows abruptly and flows for a mile through a gorge twenty to forty rods wide. The expansion and the narrows present each its own but related problem.

The expanded portion of the valley, about one mile by two, is bounded on the south by a boulder clay bluff sixty feet high; on the north by lower

and gentler slopes and is invaded near the east end by a flat spur projecting like a dam from the north side nearly to the bluff on the south. Near the south end of the dam the stream has cut a narrow gap thirty feet deep. The lower ten feet exposed in the gap is shale with a thin cap of flinty limestone. The upper twenty feet of the dam is glacial clay with the exception of a little poorly stratified gravel and sand at the south end of the dam near the creek. These features present on their face the characteristics of a drift-dammed lake drained by the down cutting of its outlet. The supposed lake bottom is underlaid, so far as discoverable, by six feet of alluvium on top of the flinty limestone. The flat-topped dam appears to be a terrace and is accordant in level with other terrace fragments in the valley of West Little Sugar creek above. In the south bluff the boulder clay is interrupted for a few rods by ten feet of finely laminated lacustrine silts, the bottom of which is at about the same level as the terrace tops.

Various hypotheses may be entertained; (1) The expansion of the valley is due to the lateral corrasion and shifting of the preglacial stream over the surface of the resistent flinty limestone. The whole valley was filled with glacial clay. The interglacial stream had a temporary base level fifty feet higher than at present and cleaned out the filling down to the terrace level (510 feet above the sea). During this process a tributary stream from the south cut a valley out of the boulder clay down to the terrace level, which was afterward filled with silt. By a lowering of the base level in the Wabash the stream was enabled to cut down the dam and to clear out the valley to the present level, draining the lake and leaving fragments of the valley filling as terraces.

(2) The preglacial and interglacial course of the stream was northeastward into the valley of East Little Sugar Creek. A readvance of the ice left a till dam across the former course and the portion of the present valley through the narrows is entirely postglacial. The complete sequence of events is not so clear as could be wished.

(3) The resistance of the two limestone strata which outcrop along the Wabash bluff and over a belt about two miles wide, west of the bluff, may account for the southward course of East Little Sugar Creek, for the narrows of the lower end of the valley and for the single gap in the bluff through which the waters of the system escape to the Wabash plain.

*Period of Ravine Cutting.*—The valley slopes of the ultimate tribu-

taries are so steep and the ravines are so narrow and sharp as to prevent cultivation and they are in most places forested. The frequent occurrence of large trees, one hundred to two hundred years old, in the bottom of the ravines, indicates that the present rate of downward corrasion is very slow, and that possibly the dissection of the region in the drift area was mostly accomplished during the period of ice melting and the succeeding period of bare ground, before the surface was covered with vegetation.

*Culture.*—The alluvial lands in the valleys are chiefly occupied by corn fields. The broken upland areas between the ravines are inconvenient for farming but many of the small fields produce good corn, oats and hay, especially hay. The only way by which cuts, fills, and bridges can be avoided in road building is to run the roads on the narrow divides between the heads of ravines. Coal mines are numerous. Along the front of the Wabash bluffs shale and coal are accessible near the surface and four large brick and tile factories have been established. The new industries have multiplied the population of West Terre Haute by five in ten years, and have caused three considerable villages to spring up from nothing in the same time.

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# Collecting Area of the Waters of the Hot Springs, Hot Springs, Arkansas.[1]

By A. H. Purdue.

*Introduction.*—The conclusions in this paper were reached in the course of field work on the structure and stratigraphy of the area about Hot Springs during the summer of 1909. The paper is written with the as- tion is made partly because geologists in general have come to think of most of the ground water as having such origin, and partly because the sumption that the waters of the hot springs are meteoric. This assump- recent studies of Mr. Walter Harvey Weed upon the waters of these springs clearly indicate that they are meteoric.[2]

*Topography of the Highlands of Arkansas.*—The highlands of Arkansas and the eastern part of Oklahoma are divided into a northern and a southern part, separated by the valley of the Arkansas River. The northern division consists of the Boston Mountains, which are a dissected plateau, reaching the height of somewhat more than 2,200 feet above sea level, and a much lower area to the north of them. The southern division consists of the Ouachita Mountains, which cover an area about 60 miles in width. These mountains consist of ridges, the direction of which is in the main east and west and some of which surpass 2,000 feet in height.

*Topography of the Area About the Hot Springs.*—The topography in the vicinity of the hot springs is indicated by the accompanying relief map (Fig. 1). The springs (indicated by the cross) emerge from the western end of Hot Springs Mountain, which is known as Indian Mountain east of West Branch of Gulpha Creek. Immediately north of Hot Springs Mountain is North Mountain, which continues west of Hot Springs Creek as West Mountain. Three miles west of the springs West Mountain swings around in a horseshoe curve and extends northeastward, and is known as Sugarloaf Mountain. Hot Springs Creek, a considerable stream, flowing southward, carries off the overflow from the hot springs and the drainage of a portion of the valley just south of Sugarloaf Mountain.

[1] By permission of the Chief Geologist, U. S. Geol. Surv.

[2] The hot springs of Arkansas. Senate Document No. 282, p. 90, Washington, D. C., 1902. Prepared under the supervision of the Secretary of the Interior.

This valley is from a mile to a mile and a quarter in width. About two miles northeast of the hot springs, where West Branch of Gulpha Creek cuts through North Mountain, is a limited area with an elevation of about 620 feet. The greater part of the surface, however, stands above the 700-foot contour, and the highest hills exceed 800 feet. The highest elevation at which any of the springs emerge is about 640 feet.

Fig. 1. Relief Map of the Hot Springs Area.

*Stratigraphy of the Area About the Hot Springs.*—The surface rocks about the hot springs are shown in the following section:[3]

[3] With the exception of the Stanley shale and the Hot Springs sandstone, these names were first applied to the formations as they appear in Montgomery County, Arkansas.

| | | |
|---|---|---|
| **Carboniferous—** | | |
| Stanley shale | 3,500 | feet. |
| Hot Springs sandstone | 100 | " |
| **Age unknown—** | | |
| Arkansas novaculite | 380 | " |
| Missouri Mountain slate | 50 | " |
| **Ordovician—** | | |
| Polk Creek shale | 210 | " |
| Bigfork chert | 570 | " |

The Bigfork chert is in layers from two to twelve inches thick. Throughout a good portion of the formation it consists almost entirely of chert, but in parts the layers are separated by thin beds of shale, and in other parts shale is the main constituent. The chert is very brittle and intensely fractured from the folding it has suffered.

The Polk Creek shale overlies the Bigfork chert, and is a very black, somewhat silicious shale, though soft enough from its graphitic nature to soil the fingers in handling. The upper part contains a few thin silicious beds, but the lower part is wholly shale.

The Missouri Mountain slate as it occurs in the vicinity of the hot springs is a red to brown or yellow shale, depending upon the stage of weathering. Further west in the Ouachita area it is a true slate.

The Arkansas novaculite as it is exposed in the city of the hot springs consists of three parts: A lower, massive one 275 feet thick, made up of heavy beds of much fractured novaculite. It is from this part of the formation that the Arkansas abrasives are secured. This is followed by fifty-five feet of very black clay shale, weathering in places to light gray; and this by fifty feet of what appears to be rotten, porous novaculite. The section of the novaculite formation over the Ouachita area varies greatly with the locality.

The Hot Springs sandstone[4] is a gray, quartzitic sandstone in beds from three to eight feet thick. The basal ten feet or more is conglomeratic. It is from this formation that most of the hot springs issue, which fact, however, is accidental and consequently not significant.

The Stanley shale is composed mainly of black to green clay shale, though a large per cent of it consists of rather soft, greenish sandstone. This shale skirts Hot Springs and West Mountains. While a large part

[4] This name has not been used before in Arkansas.

of the city of Hot Springs stands on this formation, only the waters of those springs that issue at the lowest levels move through it.

*Structure and Rocks of the Highland Area.*—The general structure of the highland area is that of a broad syncline with its trough in the Arkansas Valley. The rocks of the Boston Mountains and the area to their north lie for the most part horizontal, but in the south half of the Boston Mountains they dip perceptibly to the south, passing in the Arkansas Valley under several thousand feet of younger rocks.

The general structure of the Ouachita area is that of an anticlinorium dipping southward under the mesozoic and tertiary rocks, and northward beneath the Arkansas Valley. The rocks for the most part are intensely folded, to which, with erosion, is due the narrow valleys and parallel ridges of the area. The hot springs are located in the eastern part of this area.

The folds in the main have an east-west direction, but at Hot Springs and for some distance to the west their direction is northeast-southwest. The individual folds are as a rule not continuous for great distances, but are short and overlap each other laterally. Thrust faults, approximately parallel to the strike and of many hundred feet displacement, are common in the Ouachita Mountains and the Arkansas Valley.

*Structure of the Area About the Hot Springs.*—Like the remainder of the Ouachita region, the area about the hot springs is intensely folded. The folds are closely compressed and are all overturned to the south. As a result the dips are to the north. Some of these are as low as 15 degrees, and they seldom exceed 60 degrees. This means that at the points of greatest overturning the rock layers lie literally upside down, and in folding have described an arc of 165 degrees.

*Possibilities of Ground-Water Flowage.*—While the altitude of the Boston Mountains is sufficient to give the ground-water enough head for it to emerge at the height and distance of the hot springs, the intervening structure makes such impossible. The closely compressed folds, overlapping, and faulting of the Ouachita area are such as to prevent the uninterrupted movement of ground-water except for short distances. Likewise the stratigraphy, structure and topography to the south of the hot springs eliminate that area as a possible source of the water; and the same is true of the highlands of central and eastern Kentucky, Tennessee and Alabama and the intervening area.

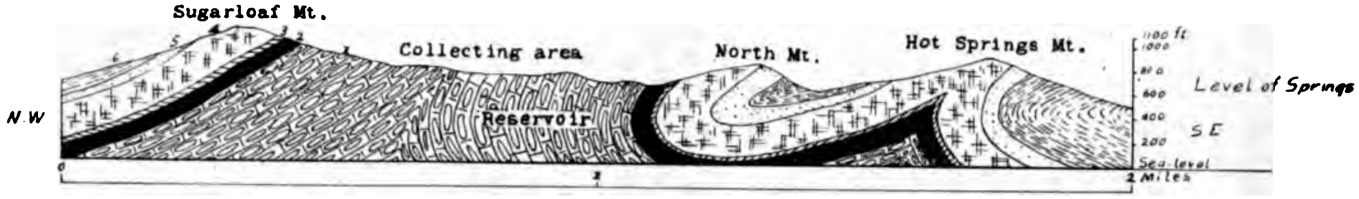


Fig. 2. Northwest-southeast section at Hot Springs.

1. Bigfork chert.
2. Polk Creek shale.
3. Missouri Mountain slate.
4. Arkansas novaculite.
5. Hot Springs sandstone.
6. Stanley shale.

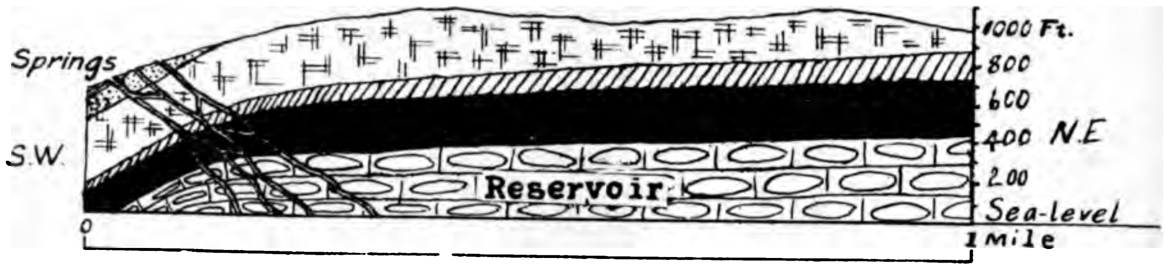


Fig. 3. Northeast-southwest (longitudinal) section of Hot Springs Mountain, showing the hypothetical water conduits at the plunging end of the anticline. Symbols same as in Fig. 2.

*The Collecting Area.*—It follows from the above that the collecting area must be in the near vicinity of the springs, and a study of the topography, stratigraphy and structure thereabout locates it with reasonable certainty. A glance at the section (Fig. 2) from Sugarloaf Mountain southeastward through Hot Springs Mountain will indicate the collecting area. The surface of the overturned, anticlinal valley between Sugarloaf and North Mountains is higher than the level of emergence of the springs. The rocks outcropping over the area are the Bigfork chert and the Polk Creek shale, the former occupying most of the area.

The considerable thickness of the Bigfork chert, its much fractured nature and the thin layers of which it is composed, all combine to make it a water-bearing formation of unusual importance. The greater number of the fine springs in the Ouachita area between Hot Springs and the western border of the state come from this horizon. In many places this formation occurs in anticlinal valleys with its highly inclinal beds truncated, affording the most favorable condition for the intake of water. A glance at figure 2 will show that these conditions obtain in the area between North Mountain and Sugarloaf Mountain. In addition to the favorable structure for the reception of water there is the stratigraphic condition for its retention brought about by the overlying Polk Creek shale. As a consequence of the topography, structure and stratigraphy the water is collected in the basin shown in the map (Fig. 1), conducted through the Bigfork chert beneath the North Mountain syncline, and rises in the Hot Springs anticline, at the western end of which it emerges in the hot springs. Including several of very weak flow, there are said to be seventy-two of these springs, and they are confined to a narrow strip about a quarter of a mile long.

The exact location of the springs is attributable to the southwestern plunge of the Hot Springs anticline, and as has been stated by Mr. Walter Harvey Weed[5] probably to fracturing and possible slight faulting in the process of folding, as shown in figure 3.

While not relevant to the title of the paper, it might be added that the considerable number of dikes in the immediate vicinity of the hot springs, the large number (eighty are known) only a few miles to the south on and near the Ouachita River, and the areas of igneous rock at Potash Sulphur Spring, Magnet Cove and other places, force the sugges-

[5] Loc. cit.

tion upon one that the waters of the springs owe their temperature to passing over hot rocks or the vapor from such in some part of their underground course.[6] The fact that these are practically[7] the only hot springs within the Ouachita area, though there are scores of cold springs issuing from the same formations and under practically the same geologic relations, gives this suggestion great weight; but inasmuch as some of the springs are said to be unusually radio-active, there is the alternative suggestion that atomic decomposition in igneous rocks (which may have lost their magmatic heat) is the source of the high temperature of the water.

Fayetteville, Ark.

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[6] Dr. J. C. Branner has already called attention to this as the probable source of the heat. See Geol. Surv. of Ark., Report on Mineral Waters, pp. 9 and 10.

[7] Recently a spring, said to have a temperature of 98° to 100° F., has been discovered issuing from the Arkansas novaculite in the bed of the Caddo River, at Caddo Gap, Montgomery County.

# WHERE DO THE LANCE CREEK ("CERATOPS") BEDS BELONG, IN THE CRETACEOUS OR IN THE TERTIARY?

By OLIVER P. HAY.

CONTENTS.



## HISTORICAL RÉSUMÉ.

Ever since the beginning of our knowledge of the geology of the Western plains and the Rocky Mountains there have existed contentions regarding the various deposits to which the names Laramie and Fort Union have been applied. These contentions have concerned the grouping of the various beds, the geological horizons to which the deposits of different basins and of different levels should be referred, and the members to which the names Laramie and Fort Union respectively should be restricted. Up to about the year 1896 certain deposits in the Judith River basin and others in Montana, Wyoming, Colorado and New Mexico were all regarded as the products of a single geological epoch and were all called Laramie. Although as early as 1860, or even earlier, some geologists, especially Dr. F. V. Hayden and Professor Leo Lesquereux, basing their opinion on the fossil plants, held that all or the greater part of the deposits in question belonged to the Tertiary, the prevailing opinion up to 1896 was that the Laramie, taking the term in its widest sense, was the uppermost portion of the Cretaceous. It may be said, however, that Professor Cope in his great work "The Vertebrata of the Tertiary Formations of the West" referred the Laramie, as well as the overlying Puerco

(including what is now known as the Torrejon), to the "Post-Cretaceous," a group holding a position between the Cretaceous and the Tertiary. He had previously assigned the Puerco to the Eocene. However, in 1887 (Amer. Naturalist, xxi, pp. 446, 450) he transferred this "Post-Cretacic System" to what he called the Mesozoic realm. In the year 1896 Messrs. S. F. Emmons, Whitman Cross and G. H. Eldridge published their "Geology of the Denver Basin," in which the previously so-called Laramie in the region of Denver, Colorado, was shown to consist of three distinct formations. The name Laramie was by them restricted to the lowest member of these, the succeeding formations being called respectively the Arapahoe and the Denver. The last two had, however, already been recognized, named and published by Eldridge and Cross as early as 1888.

Although the authors of the Geology of the Denver Basin referred to the Upper Cretaceous the three formations mentioned, Whitman Cross (op. cit., p. 206, seq.) makes a strong argument in favor of including the Arapahoe and the Denver in the Tertiary. His plea was based especially on the existence of a great stratigraphical break between the lower and the middle of the three formations and on the evidence furnished by the fossil plants. Certain deposits in Middle Park, Colorado; others near Canyon, Colorado; others in the Huerfano basin; certain ones along the Animas River; still others in New Mexico, beneath the Puerco; and the so-called "Ceratops" beds of Wyoming were all provisionally correlated with one or other of the formations in the Denver basin.

It is interesting, therefore, to observe that about 1887 and 1888, while Cope was endeavoring to raise the boundary between the Mesozoic and the Cenozoic to a position above what is now known as the Torrejon, Cross was trying to depress it to the parting between the Arapahoe and the formation below it.

It was thought by Cross that the beds of the Judith River valley might be the equivalent of the Arapahoe beds; but it has since been conclusively shown by Stanton and Hatcher that, instead of being younger than the deposits called by Cross the Laramie, the Judith beds are older than the Fox Hills, older than the upper part of the Pierre.

Within the past two years the discussion of the subjects named above has again broken into flame and a number of papers have appeared, all presenting most instructive facts and suggestions, but very diverse con-

clusions.[1] Whether the name Laramie shall be restricted to the lower of the three divisions found in the Denver basin and its equivalents elsewhere, as proposed by Cross and Eldridge, Knowlton and Peale; or to one or both of the upper divisions, as advocated by Veatch; or retained to designate all the formations between the Fox Hills and the Fort Union; or wholly abandoned, is yet to be settled; and with this I have nothing to do. It is the purpose of the present paper to show that those deposits that lie above the Fox Hills and are known to contain remains of dinosaurs; more specifically the Laramie, as understood by Cross and Eldridge; the Arapahoe and the Denver of Colorado; the Lance Creek, or "Ceratops," beds of Converse County, Wyoming; the Hell Creek beds of Montana; and the beds underlying the Puerco in New Mexico, ought not to be referred to the Tertiary, but to be retained in the Upper Cretaceous.

## 2. Necessity for Accurate Correlation of the Primary Divisions of the Geological Column in the Different Continents.

It appears to the writer that it is a matter of great importance that the primary divisions of geological time, the ages and the periods, and the corresponding systems of rocks of all parts of the world should as far as possible coincide. By this is meant that geologists should not (to employ an illustration) include in the Lower Cretaceous any deposits of one continent that were being formed synchronously with Jurassic deposits of another continent. Nor ought they to include in the Tertiary of America any formations that are the time equivalents of European Cretaceous formations. It may be a matter of great difficulty to attain agreement in some cases, but it ought to be resolutely striven after. And in this connection the writer indorses fully the quotation made by Mr. Cross (Proc. Wash. Acad. Sci., xi, p. 46) from Dr. C. A. White's address. It may be added that modification of the primary divisions ought to be made by international bodies of geologists and paleontologists.

The reasons why the primary divisions of geological history should be fixed as accurately as possible, even though arbitrarily, seem to be simple enough. Geology is the history of the development of the earth and its

[1] Veatch, A. C., Amer. Jour. Sci. (4), xxiv, 1907, pp. 18-22.
Cross, Whitman, Proc. Washington Acad. Sci., xi, 1909, pp. 27-45.
Knowlton, F. H., Washington Acad. Sci., xi, 1909, pp. 179-238.
Stanton, T. W., Washington Acad. Sci., xi, 1909, pp. 239-293.
Peale, A. C., Amer. Jour. Sci. (4), xxviii, pp. 45-58.

inhabitants. For sufficient reasons we divide this history into principal and subordinate portions, each having its own characteristics. Each continent has had its own course of development, physical and biological, this course sometimes agreeing only in a general way with that of other continents, being perhaps ahead of them or behind them, possibly sometimes only different. In order to compare and describe contemporary conditions in different lands there must be a few fixed dates from which to reckon the march of time and progress. These dates are found in the limits between the primary divisions, as that between the Silurian and the Devonian or that between the Cretaceous and the Tertiary. In a similar way we orient the history of even a savage people with reference to such dates as the founding of Rome and the birth of Christ.

### 3. The Primary Divisions of Geological Time Are Not Usually Indicated by Great Unconformities.

Inasmuch as those geologists and paleontologists who favor the reference of the Arapahoe and the Denver beds of Colorado, the Lance Creek beds of Wyoming and the Hell Creek beds of Montana to the Eocene, give as their principal reason therefor the existence of a great unconformity between the Arapahoe and the formation immediately below it, while there appears to be no similar unconformity below the Fort Union, it may be worth while to examine the adequacy of the reason. I believe that it is fallacious.

It is possible that, as Chamberlin and Salisbury suggest in their general work on geology (Geology, iii, p. 192), there is a natural basis for the larger divisions of geological history; that this basis is to be found in the profounder changes in the earth's crust; and that this basis is of world-wide application. This suggestion may be accepted as valuable without its arousing the expectation that a great stratigraphical break will be discovered everywhere between each great rock system and its predecessor and its successor. As a matter of fact, as geological history is now understood and now divided, such breaks are not commonly found. I will quote from Geikie's Text-book of Geology, ed. 4, 1903, p. 1081:

> Though no geologist now admits the abrupt lines of division which were at one time believed to mark off the limits of geological systems and to bear witness to the great terrestial revolutions by which these systems were supposed to have been terminated, nevertheless the influence of the ideas which gave life to these banished beliefs is by no means extinct.

On page 981 the author quoted, in speaking of the Old Red Sandstone, says:

> * * * in innumerable sections where the lowest strata of the system are found graduating downward into the top of the Ludlow group; and where its highest beds are seen to pass up into the base of the Carboniferous system.

On page 982 one reads as follows:

> The rocks termed Lower Devonian may partly represent some of the later phases of Silurian life. On the other hand, the upper parts of the Devonian system might in several respects be claimed as fairly belonging to the Carboniferous system above.

As to the relation of the Lower Carboniferous to the Devonian, Geikie (Text-book, p. 1014) says:

> Both in Europe and America it may be seen passing down conformably into the Devonian and the Old Red Sandstone. So insensible indeed is the gradation in many consecutive sections where the two systems join each other that no sharp line can be drawn between them. The stratigraphical passage is likewise frequently associated with a corresponding commingling of organic remains.

Chamberlin and Salisbury (Geology, ii, p. 499) tell us that the transition from the Devonian to the Mississippian seems to have been accomplished without notable deformative movement. Also (p. 518) it is stated that the Devonian fauna passed by graduation into the Mississippian.

There exists in many places the same doubt regarding the boundary line between the Carboniferous and the Permian. Geikie (Text-book, p. 1064) states that in the Midlands and the west of England no satisfactory line can be drawn between the two systems; (p. 1065) that the flora of the older Permian rocks presents many points of resemblance to that of the Carboniferous; (p. 1063) that in North America no good line of subdivision exists between Permian and Carboniferous; so certain deposits are called Permo-Carboniferous; (p. 1077) that in Russia the Permian attains an enormous development, the horizontal strata nearly lying conformably on the Carboniferous.

Of the Permian of North America Chamberlin and Salisbury write (Geology, ii, p. 620):

> The upper Barren Measures are commonly separated from the Pennsylvanian on the basis of the plant species rather than because of any stratigraphic break at their base.

The Artinskian of Russia is placed in the Permian by Lapparent and Geikie, but in the Carboniferous by Tschernyschew, a distinguished Russian geologist.

Similar difficulties are encountered in various parts of the world by geologists when they attempt to draw the line between the Paleozoic and the Mesozoic systems. Chamberlin and Salisbury (Geology, ii, p. 631) have this to say:

The Permian system of Europe seems to be more closely allied, stratigraphically, with the Trias than with the Carboniferous, and while the same is true of the western part of America, the opposite is true for the eastern part.

We have the statement of Geikie (Text-book, p. 1084) that in some regions, as in England, no very satisfactory line of demarcation can always be drawn between Permian and Triassic rocks.

Nor are geologists free from embarrassments when they endeavor to classify the Mesozoic and the Tertiary formations. The Rhætic is arranged by Geikie in the Triassic, by Lapparent in the Jurassic. Clark and Bibbins express doubt regarding the position of the two lower divisions of the Potomac formation of the eastern United States. They refer them provisionally to the Jurassic; the other two divisions are unhesitatingly placed in the Lower Cretaceous. According to Chamberlin and Salisbury, the fossils of the Trinity division of the Comanchean system have raised the question of its reference to the Jurassic. An indefinite number of similar cases could be cited.

The illustrations presented show that the great divisions of geological record are not even commonly separated by physical breaks, great or small. It would be quite as easy to show that important unconformities occur within the limits of systems of rocks. A few cases only need be cited. The following is quoted from Geikie (Text-book, p. 1007):

The Old Red Sandstone of Britain, according to the author's researches, consists of two subdivisions, the lower of which passes down conformably into the Upper Silurian deposits, the upper shading off in the same manner into the base of the Carboniferous system, while they are separated from each other by an unconformability. * * * [In Scotland] it consists of two well-marked groups of strata, separated from each other by a strong unconformability and a complete break in the succession of organic remains.

Geikie states further (p. 1146) that a considerable stratigraphical and paleontological break is to be remarked at the line between the Portlandian and the Purbeckian. Chamberlin and Salisbury (Geology, ii, p. 639) tell us that the close of the Paleozoic was marked by much more considerable geographic changes than the close of any period since the Algonkian. The statement is qualified by the remark that these changes may be said to have been in progress during the Permian rather than to have occurred at its close.

4. THE PRINCIPAL DIVISIONS OF GEOLOGICAL HISTORY ARE BASED ON FOSSIL ORGANISMS.

It may therefore be confidently affirmed that the primary divisions of geological history, as this history is now understood, are not based on unconformities and deformations, great or small, between the successive formations, but they are based on the history of the plants and animals whose remains have become entombed in the rocks. I will here quote from Lapparent (Traité de Géologie, ed. 5, p. 717):

> Il résulte de ces diverses considérations que les seules ressources de la stratigraphie, si précieuses et si indispensables qu'elles puissent être, sont insuffisantes pour l'établissement des grandes divisions de la géologie. Il faut donc recourir à quelqu'argument d'une portée plus générale. Cet argument, nous allons le trouver dans la considération des faunes et des flores fossiles.

It must not be supposed that the writer wishes to underestimate the value to the geologist of changes in the materials that constitute successive beds, of deformations of surfaces, or of unconformities, erosional and angular. All these indicate the physical changes that the earth was undergoing and mark the subordinate and more or less local divisions of geological history. Naturally the geologist in the field searches for such interruptions in the course of deposition and, following a bent very human, he may come to attach somewhat undue importance to them. In any case, however, final recourse must be had to the fossils enclosed in the rocks. Fossils are, to use a figure, the sands that, from the hourglass of the universe, have in an uninterrupted stream dropped into the successive strata to mark the passage of time. Local interruptions of sedimentation enable us to note the changes undergone by the organisms that then existed; but whether there were breaks in deposition or not, the

evolution of the organisms went steadily on. The smaller divisions of time are marked by the less important changes that the animals and plants suffered; while the primary divisions are signalized by the profounder modifications of the living beings. These primary divisions are often indicated by such phrases as the age of mollusks, the age of fishes, and the age of mammals. As there were no universal cataclysms that characterized the terminations of the ages and the eras, so there were no sudden changes in the nature of the animals and the plants. The boundaries between the successive ages and the successive eras must therefore be more or less arbitrarily drawn. If one era is characterized by numerous powerful reptiles and a few inconspicuous mammals, while the next era presents mammals as the dominant animals, the reptiles as decadent, we must draw the line to suit our convenience and to express best the facts; but in the end it will be drawn more or less arbitrarily.

To appreciate the futility of seeking for great unconformities between the rock systems one has only to consider the relations of the Upper Cretaceous to the Tertiary in Europe. Lyell regarded the Thanet sands and certain equivalents in France and Belgium as the base of the Eocene. Between this and the Upper Cretaceous there appeared to be one of the profoundest breaks in geological history. Lyell says that the interval between the Upper Cretaceous and the Eocene must have been greater than that between the Eocene and the present. More recent investigations have shown that even in the north of Europe there are deposits of no great thickness that partly fill the gap between the two systems; while it is almost filled in the south of that country.

The conclusion applicable to the question being considered which I reach is that the magnitude of the break below the Arapahoe formation in the Denver basin has little or nothing to do with the determination of the boundary line between the Mesozoic and the Cenozoic. The position of this line is to be settled through the study of the organic remains found below and above the unconformity and the comparison of these with the fossils found at corresponding levels in regions geologically better understood. If the ensemble of the organisms found in the Arapahoe, the Denver, the Lance Creek and the Hell Creek beds, is essentially of Upper Cretaceous nature, on comparison with accepted standards, those beds belong to the Mesozoic, not to the Cenozoic, notwithstanding the great unconformity.

As has already been said and is well known, the base of the Eocene was established just below the Thanetian of England and its continental equivalents; and this line of separation of the Cenozoic from the Mesozoic has been recognized by practically all geologists since Lyell's time. Considering the great gap between the two systems, as known in Europe at that time, the separation did not appear to be at all an arbitrary one. In his "Text-book of Geology," edition of 1896, Geikie placed the Montian in the Eocene, but in the edition of 1903 this formation is restored to the Upper Cretaceous. Lapparent, too, draws the line above the Montian. Nor does this manner of division appear to arouse objections on the part of the paleontologists.

If, therefore, American geologists and paleontologists wish to have the boundary line between the Mesozoic and the Cenozoic of their country coincide with that of Europe, the type continent of the base of the Eocene, it will be necessary, unless there are compelling reasons for the contrary, to make the base of our Eocene the equivalent of the Thanetian of Europe. I believe that geologists and paleontologists generally will give assent to this proposition.

It is well understood that in the determination of the level of any geological formation not all kinds of fossils are of equal value; some are indeed of little value. It is agreed that the marine animals record most accurately the progress of geological time, because of their abundance, their wide distribution, the slow and steady changes which they undergo during geological periods, and the facility with which they become entombed in accumulating sediments. Furthermore, of marine species the pelagic forms are of greater value, because their remains are dropped indiscriminately into deposits of all kinds, thus enabling geologists to correlate formations widely separated and composed of very different materials. Terrestrial animals are of less value. They are subject to rapid and extreme changes in their environment through changes in climate and through sudden migrations. They suffer accordingly rapid modifications in their structure or sudden extinction. They are also less likely to be preserved in the rocks. Every shell in an oyster bed may be preserved, while from a million horses but a single tooth may escape destruction. In an interesting address at the meeting of the British Association at Montreal, in 1884, Blanford gave it as his opinion that determinations of

geological age based on terrestrial and freshwater faunas and floras only are extremely likely to be incorrect.

Unfortunately for us, the deposits in which we are now especially interested contain few or no marine organisms, but abundant freshwater and terrestrial animals and numerous plants. We must therefore reach our conclusions by somewhat indirect methods and must be on our guard against errors. Still more unfortunately for us, the paleozoologists and the paleobotanists have not attained the same results from their studies.

### 5. The Value of Plants as Indices of Geological Dates.

I trust that the paleobotanists will not charge me with trying to disparage their science when I proceed to show that, in the present case at least, their results are less to be depended on than those obtained by the paleozoologists. Without doubt, the plants have as interesting, as trustworthy, and as valuable a story to tell, when rightly deciphered, as do the animals. It seems, however, that in some cases, other than the one before us, the significance of fossil plants has not been rightly comprehended. In Blanford's address, cited above, he mentions two important cases in which the determination of the age of certain formations have contradicted those made from the marine animals. One case is found in the Gondwana system of India, where, as Blanford says, "we have a Rhætic flora overlying a Jurassic flora and a Triassic fauna above both." Again he states that "in Australia we find a Jurassic flora associated with a Carboniferous marine fauna and overlain by a Permian freshwater fauna."

The following is quoted from Lapparent (Traité, p. 718):

> A plus d'une reprise, l'étude des flores terrestres a paru donner des indications contradictoires avec celles des faunes marines; et en dernière analyse la question a toujours été tranchée en faveur de ces dernières.

Geikie makes the following observation:

> Certainly a number of instances are known where an older type of marine fauna is associated with a younger type of flora.

One reason why plants, at least those of the northern hemisphere, which have existed since the beginning of the Upper Cretaceous, seem to be of only secondary value in correlating formations is found in their apparently extreme conservatism. While the species have changed, the genera have changed little. As an illustration of this, one may take the list of plants published by Doctor Knowlton (Wash. Acad. Sci., xi, 1909,

p. 219) as occurring in what he is pleased to call the Lower Fort Union, but which includes the Lance Creek and Hell Creek beds and their supposed equivalents. One might almost imagine it to be a list of plants found in a recently investigated corner of the world on the latitude of Louisiana. On page 225 it is stated that a number of species are yet living, while others are so obviously close to living species as to be separated with difficulty. Such inert organisms, subject also to all the vicissitudes of life on the land, can hardly be regarded as good indicators of the passage of time. Since that epoch the genera, families, and even orders of warm-blooded vertebrates have almost completely changed.

The opinion held by some distinguished geologists and paleontologists that the so-called Laramie beds, or all of these except the lowest, belong to the Tertiary appears to have rested until recently, at least, mostly on the statements of Professor Leo Lesquereux, the paleontologist of the Hayden Survey. He and Dr. Hayden at first regarded these deposits as belonging to the Miocene, but later as belonging to the lowermost Eocene. Passing over Lesquereux's earlier writings I refer to one of his latest utterances on the subject, found in the eighth volume of the monographs of the Geological Survey of the Territories, part three, published in 1883. On page 109 Lesquereux makes this statement:

> The flora of the Laramie group has a relation, remarkably defined, with that of Sézanne.

Now, the flora of Sézanne, a town in France, comes from beds that belong to the Thanetian, at the very base of the Lower Eocene. Lesquereux's statement is followed by a table of the species which he supposed had been found in the Laramie at various localities. The beds at some of these localities are now known to be somewhat older than any Laramie, those at one or two localities a little younger than Laramie. In the table is a column in which are checked off the species of Laramie plants that Lesquereux believed to be identical with or closely related to species found at Sézanne; in another column the species that he supposed were found also in the Oligocene of Europe; in a third column those that he believed to occur also in European Miocene deposits. Naturally, one would expect, in view of Lesquereux's statement quoted above, that the identical and closely related species of the Sézanne column would outnumber those of the Miocene column. On the contrary, only three species were regarded by him as identical with Sézanne species, while twenty-

seven species are recorded as identical with European Miocene species. If we count in each case the plants that were supposed to be closely related to the European species, but not identical, we find twenty-five in the Sézanne column and thirty three in the Miocene column. Adding the identical and the related species in each case it is seen that there are in the Sézanne column twenty-eight species, sixty in the Miocene column. Therefore, it becomes difficult to understand how Professor Lesquereux derived his conclusion from his premises. What his table really proved was that the Laramie deposits belong to the Miocene. Had Cope and other paleontologists examined the table itself, instead of accepting the author's statement regarding it, they would either have distrusted the evidence from the plants more than they did or would have concluded that the dinosaurs ranged up into the Miocene.

It is not to be supposed that all paleobotanists accepted Lesquereux's views. These views were strongly opposed, especially by Newberry, as early as 1874 and as late as 1889. The following is quoted from Newberry (Trans. N. Y., Acad. Sci., ix, 1889, p. 28):

If Prof. Cope had not accepted Mr. Lesquereux's conclusion in regard to the age of the deposit [at Black Buttes], and had recognized the fact that there are no Tertiary plants in the true Laramie, he would have seen that there is no discrepancy between the testimony of the plant and animal remains.

It is to be taken into consideration here that Newberry believed that the Laramie was directly overlain by the Fort Union. The latter beds have usually been regarded as belonging to the Eocene. However, the following may be quoted from Lester F. Ward, who had studied especially collections of plants from the Fort Union deposits (Bull. Geol. Soc. Amer., i, 1890, p. 531):

In fact, the material from the Fort Union formation which is still in my hands inclines me to believe that there would really be, as I then stated, no inconsistency in assigning to the Fort Union an age as ancient as the closing period of the Cretaceous system.

## 6. The Completeness of Record of Animal Life as Compared With That of Plant Life.

There is, in the present state of knowledge, a great contrast between the incompleteness of the plant record above the Fox Hills formation and the fullness of the animal record. Plants are abundant throughout the

series that has been called Laramie and in the Fort Union. Again, they are found in the Green River beds, in the White River beds, and in the deposits at Florissant, Colorado. Otherwise, the record is mostly missing. On the other hand, the history of the vertebrates is quite full. Between the Fox Hills and the present time there are known probably nearly twenty distinct faunas and it has been found possible to correlate these in most cases closely with European faunas. With such a series at command, the extremes of which differ enormously, while the mean terms sometimes grade into their successors, at other times differ greatly from the next comers, the paleontologist need not go far astray in determining the proper level of each fossil-bearing deposit. It may be remarked that when the paleobotanist refers the Green River beds to the Oligocene, while the vertebrate paleontologists put them at the bottom of the middle Eocene, a serious dislocation of views is indicated.

### 7. The Beginning of the Eocene in Europe and America.

When one comes to correlate formations in America with those of distant countries great difficulties are likely to be experienced. Interruptions in stratification are not likely to occur at the same time in America and Europe and Asia. On account of differences in the character of the deposited materials, the climate, the interposition of barriers, and other features of environment, the contained organisms must differ to a greater or less extent. In the case of the beds about which exists our dispute, they are neither of marine origin nor in contact with strata of purely marine origin. Hence they cannot be compared directly with either the typical uppermost Cretaceous deposits of Europe, the Danian, nor with the Thanetian, the lowermost European Eocene. The Lance Creek beds, the Hell Creek beds, and others related to them have been produced mostly through the action of fresh waters and they contain remains of land plants, freshwater mollusks and fishes, reptiles inhabiting the water and the land, and a few terrestrial mammals. In such a situation we must have recourse to indirect means of correlation.

In the vicinity of Rheims, France, in deposits belonging to the Thanetian, there has been found a considerable number of genera and species of extinct mammals, together with some birds, reptiles, and fishes. The mammals have been studied and described by Lemoine. On the strength of this fauna these Cernaysian beds were correlated with the Puerco at a

time when this term was applied to beds now separated and known as Puerco and Torrejon. There is thus furnished a means of beginning a correlation of our land and freshwater Tertiary deposits with those of Europe; but we need ever to keep in mind the possibilities of error.

I believe that any one who may carefully compare the Cernaysian fauna with the faunas of our Puerco and Torrejon must conclude that the Cernaysian corresponds more closely with that of our Torrejon than with that of the older Puerco. I find that Osborn had reached this conclusion in 1900 (Ann. N. Y. Acad. Sci., xiii, pp. 9, 10); and in his latest matter on the subject he correlates the Torrejon with the Thanetian, or Cernaysian (Bull. 361, U. S. Geol. Surv., p. 34). Indeed, it seems not improbable that the Cernaysian is a little more recent even than our Torrejon.

It has been demonstrated that at least a part of the Fort Union formation is the equivalent of the Torrejon. Hence, wherever the latter is put the Fort Union or some part of it must go. The base of the Tertiary being drawn in Europe at the bottom of the Thanetian, there appears to be no good reason why in our country it should not be drawn above the Puerco, possibly above the Torrejon and the Fort Union. Certainly, when geologists and vertebrate paleontologists have consented to include the Puerco and the Torrejon in the Eocene they have lowered the base of the latter formation to its extreme level. To include now in the Eocene the "Ceratops" beds, the Hell Creek beds, the Arapahoe and the Denver, would be to add to it some hundreds of feet of deposits which, in the opinion of vertebrate paleontologists, contains a considerably older fauna than that occurring in the Cernaysian beds, and which with equal confidence the invertebrate paleontologists refer to the Cretaceous.

### 8. Relationship of Fauna of Lance Creek Epoch to Those of Puerco and Torrejon.

Inasmuch as those geologists and paleobotanists who favor the transference of a large part of the Laramie (as formerly understood) to the Tertiary insist that the fauna of the Lance Creek and the Hell Creek beds is more closely related to that of the Puerco and that of the Torrejon than to any Cretaceous fauna, this question must be considered. With regard to the relationships of the mammals of the Lance Creek beds to those of the Puerco and Torrejon extremely diverse views have been expressed. Marsh (Amer. Jour. Sci., xliii, 1892, pp. 250, 251) says that the mammals of the Lance Creek deposits .

are not transitional between the Mesozoic and Tertiary forms, but their affinities are with the former beyond a doubt; thus indicating a great faunal break. * * * and the great break is between this horizon [the Peurco] and the Ceratops beds of the Laramie. * * * It is safe to say that the faunal break as now known between the Laramie and the lower Wasatch [Puerco] is far more profound than would be the case if the entire Jurassic and the Cretaceous below the Laramie were wanting.

Cope (Amer. Naturalist, xxvi, 1892, p. 762), quoting from Marsh the words "the more the two [Laramie and Puerco] are compared the stronger the contrast between", adds:

It is true that no Ungulata have yet been found in the Laramie, while they abound in the Puerco, but we cannot be sure that they will not yet be found; the probabilities are that they existed during the Laramie and that it is due to accident that they have not been obtained. But the Multituberculata of the two faunæ are much alike.

Osborn (Bull. Amer. Mus. Nat. Hist., v., 1893, p. 311) writes:

This Laramie fauna is widely separated from the Upper Jurassic, and is more nearly parallel with the basal Eocene forms of the Puerco and the Cernaysian of France. * * * These conclusions are directly the reverse of those expressed by Marsh in his three papers upon this fauna.

Cross (Geology of the Denver Basin, p. 220) concludes that this difference of opinion deprives the mammalian remains of much of their value in the present discussion.

To the present writer Marsh's opinion seems to be erroneous. Geologically, of course, the Jurassic mammals are much farther removed from those of the Lance Creek beds than the latter are from those of the Puerco, Torrejon, and Fort Union. The same remark may justly be made regarding the stage of development attained by the Jurassic mammals. Systematically considered, the case is different; and the solution of the problem depends on the systematic relationships of the Jurassic mammals to those of the Lance Creek beds and of the latter to the mammals of the Puerco and Torrejon. If it shall result that all, or nearly all, of the Lance Creek mammals belonged to the Marsupialia and the Monotremata, then Marsh's opinion will be in great measure justified. If, on the other hand, it shall be shown hereafter that a large number of the Lance Creek mammals were placentals and the near-by ancestors of the Puerco and Torrejon faunas the break between the former and the latter will not be a profound one; nevertheless more important than formerly supposed by Osborn.

It must be understood that our knowledge of the mammals of the Lance Creek and related formations is of a very unsatisfactory kind. With few exceptions, all that is known of these animals has been derived from their teeth, not found in place in the jaws, but scattered singly through the rocks. Better known are the Jurassic mammals, for of these many jaws have been secured. Recently considerable light has been thrown on the marsupials of the Lance Creek and Fort Union formations through the discovery of the skull and some parts of the skeleton of *Ptilodus* (Gidley. Proc. U. S. Nat. Mus., xxxvi, p. 611). The other genera await elucidation. Osborn's statement of the situation may be accepted (Evolution of the mammalian molars, 1907, p. 95) :

It is possible that, besides Marsupials, we find here Insectivores, primitive Carnivores, and the ancestors of ancient Ungulates; but it is obvious that the determination of relationships from such isolated materials is a very difficult and hazardous matter.

Notwithstanding this appreciation of the situation, Professor Osborn has ventured (op. cit., pp. 12, 22, 115) to refer his Trituberculata, Marsh's Pantotheria, to the infraclass Placentalia. No adverse criticism can be made on this procedure, in case its tentative character is understood.

Now, while this uncertainty reigns regarding the systematic relationships of the mammals of the Lance Creek and related deposits, the case is different as soon as attention is given to the mammals of the Puerco, Torrejon, and Fort Union. Some of them betray by their tooth succession and other characters that they are true placentals. Many of them may be referred with confidence to orders and families that continued long afterwards, some of them probably to the present day.

That a considerable gap existed between the mammals of the Lance Creek formation and those of the Puerco and Torrejon is evident from the state of development of the teeth. Osborn, speaking of the teeth of the Upper Cretaceous mammals [Lance Creek] says (Bull. Amer. Mus. Nat. Hist., v., 1893, p. 321) that in none of the molars hitherto described and in none of his collection of about 400 teeth and some jaws was there any trace of the hypocone, or posterior internal tubercle. Nor was any hypocone recognized in the genera described by him in 1898 (Bull. Amer. Mus. Nat. Hist., x, p. 171). Undoubtedly, however, the hypocone is sometimes present in a rather rudimentary condition, as I have observed in teeth shown me by Mr. Gidley, of the U. S. National Museum. Nevertheless.

the teeth of all the mammals of the Lance Creek stage, except those of the Allotheria, are triangular, showing that the possessors were either insectivorous or flesh-eating in their habits.

On the other hand, there are several genera of Puerco mammals that possess a well developed hypocone and internal cingulum. In some cases, where the hypocone had no great development, the hinder internal part of the tooth had swollen so as to reduce much the gap between the successive teeth and produce a broad triturating surface. In *Polymastodon*, which must have been a vegetarian, an extensive triturating surface was secured in another way. It presents a great advance over the teeth of any of the Lance Creek Allotheria. If it is considered how slowly changes in tooth structure had advanced during the Mesozoic era we must conclude either that a considerable interval had elapsed between the Lance Creek epoch and that of the Puerco or that the animals of the latter were not descendants of the former.

There are important differences between the mammals of the Lance Creek beds and those of the Puerco as regards the size attained. Most of the former are of insignificant proportions, resembling in this respect those of the Jurassic; while many of those of the Puerco are large. Furthermore, there was in the mammals of the Puerco a far greater variety of form, structure, and systematic relationships than among those of the Lance Creek mammals. Of the latter, there have been described about twenty-five genera and about forty-five species, most of them by Marsh. Osborn has regarded himself as justified in reducing these to about ten genera, these representing a very few families. From the Puerco Matthew (Bull. 361, U. S. Geol. Surv., 1909, p. 91) recognizes twenty-nine species, belonging to eighteen genera and nine families. To what extent this increased diversification of the mammalian life of the Puerco is due to immigration we can not now tell; but it does not seem to be necessary to assume that it was due to invasion of mammals from some other region. For, in view of the interval between the two formations that is indicated by the plants and reptiles, it is possible that the Puerco mammals are the direct descendants of those of the Lance Creek epoch.

In case there was no serious interruption in deposition between the Lance Creek beds and the Puerco and Fort Union, one might expect to find close relationships between the reptiles of the two levels. Crocodiles are not abundant in either and, so far as known, no species passes from

the one formation to the other. *Champsosaurus*, belonging to another order, is found in the beds of the Lance Creek region and at Hell Creek and also in the Puerco; but probably no species is common to the lower and the upper levels. This genus, like *Ptilodus*, serves to show that, though there may have been a considerable interval between the Lance Creek and the Puerco, it was not an enormous one. The dinosaurs, which were such a conspicuous feature of the Lance Creek epoch, appear to have disappeared completely before the time of the Puerco and Fort Union. Of turtles, some families passed from the one formation to the other, but probably no species. A pleurodire, representing a large group of turtles found now mostly south of the equator, was present in the "Laramie" of New Mexico; but no member of the group is known to have existed in North America after that time. Certain other genera of turtles (*Adocus*, *Eubaëna*, *Thescelus*, *Basilemys*, *Helopanoplia*) are not known to have passed from the Lance Creek level into that of the Puerco and Fort Union; and other genera (*Alamosemys*, *Hoplochelys*, *Conchochelys*, *Amyda?*) appear to have had their beginning in the Puerco. It may further be said that, while turtles were very abundant in the Lance Creek epoch, they appear to have been very rare in the Fort Union, though of more frequent occurrence in the Puerco.

As regards the mollusks I find this statement made by Doctor Stanton (Wash. Acad. Sci., xi, p. 264), where he is speaking of a Fort Union locality in Montana:

> The Unios are all of simple type and do not include any of the peculiarly sculptured forms like those of Hell Creek, Converse County, and Black Buttes.

The plants, conservative as they are, testify even more strongly than do the animals to a considerable interval between the Lance Creek epoch and the Fort Union. According to Doctor Knowlton (Wash. Acad. Sci., xi, p. 221), out of 84 identified species found in the Lance Creek epoch ("Lower Fort Union") 68 occur in the Fort Union. Hence 16 species, nearly 20 per cent, appear to have failed to reach the higher beds. It is to be noted here that about 300 plants are known from the Fort Union and only about 200 from the Lance Creek beds. For a group of organisms that even then contained a considerable number of species yet existing, or very close to forms yet existing, the loss of a fifth of their forces, at a time when there appears to have been little change of climate, indicates the lapse of an important interval.

The base of the Eocene is usually regarded as containing a small per cent of the marine mollusks yet living; the beginning of the Miocene, about 17 per cent of yet existing species; and the beginning of the Pliocene about 36 per cent. If now plants have changed in species during the lapse of geological time with about the rapidity that marine mollusks have changed, the Fort Union beds ought to be arranged in the Lower Miocene. This would harmonize quite well with the idea that the Green River beds belong to the Oligocene.

### 9. Relationship of Lance Creek Fauna to That of the Judith River Epoch.

Having demonstrated, as I think I have, that there was, between the time of the deposition of the Lance Creek beds and those known as Puerco and Fort Union, a nearly complete change in the fauna and a considerable change in the flora, I will endeavor to show that the fauna of the former beds is closely related to that of the Judith River, a formation now recognized as being well down in the Upper Cretaceous and separated from the lowermost Laramie by about 1,000 feet of marine Cretaceous strata (Stanton, Wash. Acad. Sci., xi, p. 256). This close relationship of the two faunas has been recognized, it may be truthfully said, by all paleontologists who have given attention to the subject. For a long time it misled geologists and paleontologists into the conclusion that all the deposits in question belonged to a single epoch. Mr. J. B. Hatcher, who had collected extensively both in the Judith River region and in the Lance Creek beds, and who had studied closely the vertebrates of both regions, writes (Bull. U. S. Geol. Surv., 257, p. 101):

When considered in its entirety, the vertebrate fauna of these beds [Judith River] is remarkably similar to, though distinctly more primitive than, that of the Laramie [Lance Creek beds]. Almost or quite all of the types of vertebrates are present, though, as a rule, they are represented by smaller and more primitive forms.

Doctor T. W. Stanton, paleontologist of the U. S. Geological Survey, who examined in company with Professor Hatcher the Judith River basin, and who has given especial attention to the invertebrate fauna, records in the same bulletin (p. 121) his opinion:

When full collections are compared it will usually be easy to distinguish between Judith River and Laramie from the brackish-water fossils alone, but if the collections are meager and fragmentary it may not be

practicable to do so. * * * Taken as a whole, the fresh-water faunas of the Judith River and the Laramie are somewhat more distinct than the brackish-water faunas of the same formations, and with fairly complete collections it should not be very difficult to distinguish them in the laboratory.

When we come to compare the vertebrates of the Judith River beds with those of the Lance Creek deposits it becomes necessary practically to ignore the mammals, inasmuch as only two species of these have up to this time been discovered in the Judith River. These are *Ptilodus primævus* and *Borodon matutinus*, both described by Lambe from the Belly River beds of British America. The former of these fossils is related to species of the same genus found in the Lance Creek beds and in the Torrejon, the latter genus is of undetermined relationship.

*Fishes.*—Beginning with the fishes, there have been described from the Judith River beds eight species. In the Lance Creek beds, Converse County, Wyoming, Professor Williston (Science, xvi, 1902, p. 952) found materials which he refers to two of these species (*Mylcdaphus bipartitus*, *Lepisostcus occidentalis*). One of these fishes, *Myledaphus bipartitus*, seems to be a ray. The rays are almost wholly inhabitants of salt water; hence the persistence of this Judith River freshwater form is somewhat remarkable. A supposed sturgeon, *Acipenscr albertensis*, found by Lambe in the Belly River beds, occurs, according to Williston, in the Lance Creek beds. From the Belly River beds Mr. Lambe described a remarkable species of fish which he called *Diphyodus*. Hatcher states that similar jaws are common both in the Judith River beds of Montana and in the deposits of Converse County, Wyoming. From the Hell Creek beds of Wyoming Mr. Barnum Brown has reported the discovery of another species of the same genus.

*Tailed Amphibians.*—Of the tailed amphibians, at all times rare fossils, Cope described from the Judith River region four species, all members of the genus *Scapherpcton*. Lambe believes that he has found one of these in the Belly River beds, a fact that shows the somewhat extended distribution of the genus at that epoch. Williston found one of the species in the Lance Creek beds and Brown reported a species from the Hell Creek deposits. While it is true that these fishes and amphibians are mostly represented by fragmentary remains, these remains are usually characteristic and capable of accurate comparison. That *Myledaphus* should reappear after an interval allowing the deposition of 1,000 feet of marine

strata and probably some hundreds of feet of freshwater strata, is remarkable enough; but that it should reappear in company with its old companions, the rare *Diphyodus* and *Scapherpeton*, not to mention the more highly developed fauna yet to be discussed, is very striking. Had there occurred at both levels only some pebbles of three peculiar forms or compositions, instead of the three genera, the conclusion would have been inevitable that there was some particular connection between the two formations.

*Champsosaurus. Crocodiles.*—Coming next to the reptiles, it may first be noted that species of *Champsosaurus* occur in the Judith River beds, in the Lance Creek beds, in those of the Hell Creek region, and in the Puerco. It is probable that the species vary from one formation to the other. The same statement can probably be made regarding the crocodiles. These genera, common to all three of the formations under discussion, may be left out of consideration; although it must not be overlooked that none the less they aid in binding together the formations in which they are found. As to the crocodiles, it may be mentioned that Williston recognized, in teeth and scutes found in the Lance Creek beds, Leidy's *Crocodylus humilis*, originally described from the Judith River region. From the Judith River beds of Alberta Lambe described *Leidyosuchus canadensis*. Mr. C. W. Gilmore will soon describe a second species of the genus, collected last summer in the Lance Creek beds of Converse County, Wyoming.

*Turtles.*—As regards the turtles, certain genera have already been mentioned as appearing not to pass the line between the Lance Creek formation and the Puerco and Fort Union. My study of the fossil turtles indicates that the species of these animals rarely pass from one epoch to another. If they have ever done so they passed from the Judith River into the Lance Creek epoch. There are five or six species of Judith River turtles which are represented in the Lance Creek and Hell Creek beds by turtles of identical or very closely related species. Most of these are marked by such peculiar sculpture that they are easily recognized and some of them likewise are represented by excellent materials. I shall take the pains to give some details.

*Compsemys? obscura* Leidy was originally described from beds probably belonging to the Lance Creek epoch and found at Long Lake, N. Dakota. Not much of it is known, but the sculpture is distinctive.

It was included by Cope in his list of Judith River vertebrates. Barnum Brown found what appears to be the same species in the Hell Creek beds.

*Compsemys victa* Leidy was described from the beds of Long Lake. Its sculpture is characteristic, resembling small, closely placed, pustules, that cover all parts of the shell, and appearing in no other turtles. It is fragmentary, but very common in the Lance Creek beds. Barnum Brown has collected it in the Hell Creek deposits. Cope included it in his list of Judith River vertebrates. He also found it in Colorado, in deposits that belong to either the Arapahoe or the Denver. I am able to say that the same genus is represented by an undescribed species in the Fort Union.

*Aspideretes foveatus* (Leidy) was described from the Judith River basin. Leidy had other specimens from Long Lake, N. Dakota. There are many fragments of the species in a collection made in the Judith Basin for Cope by Charles Sternberg. A nearly complete carapace was found in the Belly River beds by Lambe. Fragments indistinguishable from the type were secured by Barnum Brown in the Hell Creek region. The carapace is ornamented by a characteristic pitting.

*Aspideretes beecheri* Hay has for its type a specimen in Yale University which lacks little more than the head and a part of the neck. Mr. Hatcher collected in the Judith River beds two quite complete carapaces which I have examined, without being able to distinguish them from the type of *A. beecheri*.

*Adocus lineolatus* Cope is a turtle that is not well known, but fragments of what appear to be the same species are not uncommon. The sculpturing is peculiar. The type was found in Colorado, in probably the Arapahoe formation. Cope included it among the vertebrates of the Judith basin, and Lambe reported it from Belly River deposits in Alberta. Barnum Brown found in the Hell Creek beds what seems to be the same species.

The genus *Basilemys* is represented by turtles of large size and an extraordinary form of sculpture. The type *B. variolosa* (Cope) has as its type a large part of the plastron and considerable parts of the carapace. This type was found in the Judith River basin. Members of the Canadian Geological Survey found good specimens of the species in the Belly River beds in British America. A second species of the genus has been discovered in beds of the Lance Creek epoch, in Custer County, Montana. The type is a complete shell. Had only fragments been found that did not

include distinctive parts, this specimen would have been regarded as belonging to *B. variolosa*. A species not certainly identified occurs in the Hell Creek beds. During the past season an undescribed, closely related species was discovered in the Lance Creek deposits in Converse County, Wyoming, by a member of the U. S. Geological Survey. Nothing resembling these turtles has ever been found in beds above those equivalent to the Lance Creek deposits. Indeed, all those turtles of the Upper Cretaceous which had the carapace and plastron sculptured in various ways, appear to have become extinct before the beginning of the Tertiary. Not long after the opening of the Tertiary, in the Wasatch, there came in the Emydidæ and the Testudinidæ, and these developed other styles of ornamentation of the shell.

Figures of all the species of turtles named above are to be found in the present writer's "Fossil Turtles of North America."

*Dinosaurs.*—Both in the Judith River beds and in those of the Lance Creek epoch the most abundant and the most conspicuous reptiles are the dinosaurs. Five families of these, belonging to four superfamilies and to two suborders, are represented in the Judith River epoch, and each of these families reappears in the Lance Creek epoch. Furthermore, many of the genera are common to the two formations and it is believed that the same is true of a considerable number of species. From the Judith River beds Cope described eight species of carnivorous dinosaurs that seem to come under the genus *Dryptosaurus*. Mr. Hatcher (Bull. U. S. Geol. Surv., 257, p. 86) mentions the occurrence of two of these, called by him *Deinodon explanatus* and *D. hazenianus*, in the Lance Creek beds. Another carnivorous dinosaur, *Deinodon horridus*, was originally described from the Judith River beds. Hatcher (loc. cit., p. 83, *Aublysodon mirandus*) believed that it was found likewise in the Lance Creek beds. Another, *Zapsalis abradens*, is thought (p. 84) to occur in both formations. The great carnivorous dinosaur described by Osborn, *Tyrannosaurus rex*, may be a descendant of Marsh's *Ornithomimus grandis*, of the Eagle formation, older still than the Judith beds.

In the herbivorous order Orthopoda are placed the remarkable reptiles called the Stegosauria. Two species, *Troodon formosus* and *Palæoscincus costatus*, are mentioned by Hatcher (loc. cit., pp. 83, 88) as being represented in the Lance Creek deposits by numerous teeth of size and pattern similar to the types, which were described from the Judith River

formation. In addition to these, Barnum Brown has described from the Hell Creek beds a large stegosaur, *Ankylosaurus magniventris*, the type of a new family. We can not doubt that some day a closely related form will be discovered in the Judith River beds; and indeed, its immediate ancestor may be Lambe's *Stereocephalus tutus*, from the Belly River deposits.

The large herbivorous dinosaurs, the Hadrosauridæ, which were accustomed to walk about on their hinder limbs only, are, according to Cope's identifications, represented in the Judith River formation by about nine species. The Lance Creek and the Hell Creek beds furnish three or four species of the family, most of which are referred to the genus *Hadrosaurus*, or *Trachodon*. Whether or not there are species common to the two formations cannot now be definitely determined; but certainly their relationships are very close.

Of all the dinosaurs that are found in the formations in which our interest is now centered the Ceratopsia have received the most careful study. What the present state of knowledge is with regard to these remarkable reptiles, may be learned from Hatcher's monograph of the group, completed and edited by Dr. Lull (Mon. 49, U. S. Geol. Surv.). Unfortunately much needs yet to be learned about them, especially about those of the Judith River forms. Approximately nine species are known from the Judith River deposits of Montana and British America; and about fifteen species are credited to the Lance Creek beds, of Wyoming, and to the Arapahoe and the Denver, of Colorado. Hatcher and Lull conclude that those of the Judith epoch are somewhat more primitive than those of the beds higher up, being somewhat smaller, with a less completely developed nuchal frill, with the nasal horn relatively larger and the supraorbital horns relatively smaller than in the younger forms. It is, however, to be noted that the nasal horn of *Ceratops*, of the Judith River epoch, is not yet certainly known. For the most part the genera are based on the characters mentioned above. They may have the importance assigned to them, but they do not indicate radical differences. Such differences might easily have arisen during an interval of moderate duration. There can be no doubt that the Ceratopsia of the higher beds were derived directly from those of the lower.

The possibility may be fully granted that further investigations may prove that few or no species of vertebrates continued from the Judith

River epoch to that which witnessed the deposition of the Lance Creek and Hell Creek beds. Nevertheless, nothing can impair the force of the evidence that many species included among the fishes, the tailed amphibians, the turtles, the crocodiles, the champsosaurians, and the carnivorous and herbivorous dinosaurs are represented in both formations by closely related forms. The remarkable thing about the matter is that the faunas of the two formations, separated by so great a thickness of strata, should be so similar. We must conclude that deposition went on rapidly in that interval, so that it may not have been so long as otherwise might appear. There could hardly have been movements of the land in that region that produced any considerable changes of climate. During the Bearpaw epoch the sea probably quietly invaded a part of the territory that had previously been occupied by the Judith River animals; but around the border of this invading sea the turtles, the crocodiles, and the many genera of the dinosaurs continued their existence and their evolution undisturbed until that sea retired. And doubtless had all those animals in that region been destroyed there was an extensive territory, nearly the whole of North America as far as the Atlantic, that harbored similar forms, from which territory new recruits could swarm in. As far away as New Jersey there were living herbivorous and carnivorous dinosaurs not greatly different from those of the Judith River beds. This appears to be true, that whatever happened to the plants between the time of the Judith River and the Lance Creek beds, nothing of serious importance happened to the animals.

By those who insist on elevating the deposits of the Lance Creek epoch into the Tertiary, a persistent effort has been made to minimize or nullify the significance of the presence of dinosaurs. As long ago as 1880 Heer wrote thus (Arctic Flora, vol. 6, pt. 2, p. 7):

> Der *Agathaumas* von Black Buttes beweist daher keineswegs, dass dort eine Tertiär-Flora zu gleicher Zeit mit einer Kreide-Fauna gelebt habe, wie Prof. Cope dies behauptet, denn ein einzelnes Thier macht so wenig eine Fauna aus, als eine Pflanzenart eine Flora. Wir können daher Hrn. King nicht beistimmen, wenn er, mit Cope und Marsh, die Laramie-Gruppe zur Kreide bringt.

Mr. Cross and Dr. Knowlton have argued that the dinosaurs might have continued on into the Eocene, and in fact did so. As to the vertebrate paleontologists, it is not probable that any of them would have asserted that this was impossible and some of them have granted the possibility. In holding that the dinosaur beds belong to the Mesozoic, they

have reasoned that, inasmuch as these animals are characteristic of the Mesozoic and are not known to occur in the Tertiary of any other region, they probably did not exist during any part of the Tertiary of this country. And certainly, there is a mass of confirmatory evidence for this conclusion. The plants have appeared to furnish evidence against it; but, in view of the discrepancy between Lesquereux's conclusion and his premises, it seems that the paleozoologists were justified in their conservatism.

Mr. Cross writes (Mon. U. S. Geol. Surv., xxvii, p. 251):

> If the dinosaurs of the Ceratops fauna did actually live in the Laramie epoch of Colorado they survived a great orographic movement and its accompanying climatic changes, and continued through the Arapahoe and Denver epochs so little modified that Professor Marsh has not detected any changes corresponding to the stratigraphic time divisions.

Since this was written it has been found that the Judith River beds, which contain so many dinosaurs, were deposited long before the time of the Laramie. We thus have proof that these dinosaurs and many other forms of vertebrates survived, without important changes, the orographic movement mentioned by Mr. Cross. It seems probable, therefore, that this movement was not so widely extended and so long continued as has been supposed. Why the dinosaurs died out finally we do not know, any more than we know why numerous other vigorous races of animals have perished from the earth. That the causes were not local is shown by the fact that in Europe likewise they became extinct just before the appearance of the Cernaysian fauna. It may be regarded as very reprehensible in them that they thus permitted themselves to perish before the Eocene came on, but we are compelled to believe the record.

In the preceding pages I have endeavored to show that the deposits of the Lance Creek epoch are well separated from those of the Fort Union, as indicated by both the fauna and the flora. In case a biological break is required between the Cretaceous and the Tertiary such a break seems to be present here. The stratigraphical break appears to be less conspicuous; yet unconformities are not absent and the character of the deposits appears to be such that there is seldom difficulty in separating the one formation from the other. Nevertheless, it seems that accurate correlation demands that the line between the Mesozoic and the Cenozoic in that region ought to be drawn at least above the Puerco and probably through or above both the Torrejon and the Fort Union. The exact position of the parting must be settled after further investigations.

## 10. CONCLUSIONS.

1. The answer that the writer would give to the question at the head of this paper is that the Lance Creek beds belong to the Upper Cretaceous.

2. In the Upper Cretaceous ought to be included also the Puerco and not improbably also the Torrejon and the Fort Union.

3. In case of a conflict between the evidence furnished by the flora and the fauna of the Lance Creek beds and those of the Fort Union respectively, the evidence obtained from the faunas is to be preferred, as being part of a more complete and better understood history. Present knowledge regarding plants seems to indicate that they were precocious, having reached something like their present stage of development long before the mammals attained anything like their present stage of differentiation. There are also indications that the floras of the western world were, during the Cretaceous, considerably in advance of those of Europe.

4. Even if it were conceded that the Fort Union belongs to the Tertiary, and that the fauna and flora of the Lance Creek epoch are more closely related to those of the Fort Union than they are to those of the Judith River, it does not follow that the Lance Creek epoch must be included in the Tertiary. A quarter before midnight on Monday is much nearer to Tuesday than it is to the previous six o'clock; nevertheless, it is not yet Tuesday.

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# Paleontology and the Recapitulation Theory.

By E. R. Cumings.

## I.

In reply to a severe critique of the recapitulation theory, or biogenetic law, by Hurst (30), Bather remarks that "If the embryologists had not forestalled them, the paleontologists would have had to invent the theory of recapitulation." (1) This may be considered as a fair sample of the general attitude of paleontologists of the Hyatt school, to which Bather belongs, toward the recapitulation theory.

Even the more conservative paleontologists, while inclined to use the theory *cum grano salis*, recognize the weight of evidence that Hyatt and his coworkers in the realm of paleobiology, have brought together, as is evidenced by the following quotation from Zittel (65): "Nevertheless embyronic types are not entirely wanting among invertebrates. The Paleozoic Belinuridæ are bewilderingly like the larvae of the living Limulus. The pentacrinoid larva of *Antedon* is nearer many fossil crinoids than the full grown animal. . . . . Among pelecypods the stages of early youth of oysters and Pectinidæ may be compared with Paleozoic Aviculidæ. Among brachiopods, according to Beecher, the stages which living Terebratulidæ pass through in the development of their arm-skeleton correspond with a number of fossil genera. The beautiful researches of Hyatt, Würtenburger and Branco, have shown that all Ammonites and Ceratites pass through a goniatite stage, and that the inner whorls of an Ammonite constantly resemble, in form, ornament and suture line the adult condition of some previously existing genus or other."

In violent contrast with this full acceptance, or this guarded acceptance of the theory on the part of the paleontologists, is the position of a considerable school of embryologists and zoologists. Perhaps no one has put the case against the theory more baldly and forcibly than Montgomery in his recent book on "An Analysis of Racial Descent" (42). He says: "The method is wrong in principle, to compare an adult stage of one organism with an immature stage of another." And again: "Therefore we can only conclude that the embryogeny does not furnish any recapitulation of the phylogeny, not even a recapitulation marred at occa-

sional points by secondary changes. . . . An analysis of the stages during the life of one individual can in no way present a knowledge of its ancestry, and the method of comparing non-correspondent stages of two species is wrong in principle." Equally sweeping is the statement of Hurst (30): "The ontogeny is not an epitome of the phylogeny, is not even a modified or 'falsified' epitome, is not a record, either perfect or imperfect of past history, is not a recapitulation of evolution."

It would seem as though two statements could not be more flatly contradictory than these of Hurst and Montgomery, and that of Bather quoted above. Nevertheless I venture to make the seemingly paradoxical assertion that both parties to the controversy may be right, for the simple reason that they are talking about quite different things. This has been nowhere better expressed than by Grabau (25). He says: "It has been the general custom to test the validity of the recapitulation theory by the embryological method: i. e., the comparableness of the changes which the individual undergoes during its embryonic period to the adults of more primitive types. Usually the comparison has been with the adults of existing types, since in most cases these alone were available for comparison. It is no wonder, then, that such comparisons have led to innumerable errors, if not absurdities, which have placed the recapitulation theory in an evil light and awakened in the minds of many serious investigators doubts as to the validity of the deductions based upon this doctrine. When, however, the *entire life history* of the individual is considered, instead of *only the embryonic period*, and when the successive stages of epembryonic development are compared with the adult characters of related types, in immediately preceding geologic periods, it will be found that the fundamental principle of recapitulation is sound, and that the individuals do repeat in their own *epembryonic* development the characters of their own immediate ancestors." (Italics mine.)

It is as a matter of fact true that the Hyatt school of paleontologists have based their phylogenies on epembryonic rather than embryonic stages —stages beginning with the nepionic or infantile—since in the nature of the case the true embryonic stages are scarcely ever accessible to the student of fossils. It is no less true that the severest critics of the theory of recapitulation have rested their case largely on the real or supposed lack of correspondence between the *embryonic* stages and the adult stages of assumed ancestors, or upon certain *a priori* considerations having to

do with the laws of development and inheritance. To the former class belong such critics as Von Baer, and to the latter class such as Hatschek, His, Hurst, Montgomery and others.

In making this statement I am aware that paleontologists sometimes compare true embryonic stages with adult stages of pre-existing types. As examples of this we might cite the comparison of the larval stage of *Antedon* with adult Paleozoic crinoids, as mentioned by Zittel; and the classic attempt of Beecher to reconstruct the ancestor of the Brachiopoda by a comparison of the phylembryonic stages of a representative series of genera of recent and fossil brachiopods. Nevertheless by far the greater number of comparisons that have been instituted by paleontologists have been between epembryonic stages of individuals and adult stages of older forms. Such comparisons are those of Hyatt, Branco, Karpinsky, Würtenburger, Buckman, Neumayr, Smith, Beecher, Clarke and others among the Cephalopoda; of Beecher and Schuchert, Raymond, Greene and Cumings among the Brachiopoda; of Jackson among the Pelecypoda; of Grabau and Burnett Smith among the Gastropoda; of Lang and Cumings among the Bryozoa; of Ruedemann among the graptolites; and of Beecher, Girty, Lang and others among the corals. To many of these researches I shall refer later.

I am also not unmindful of the fact that many of those who are not primarily paleontologists recognize the fact that development does not terminate with the completion of the embryonic stages, and that recapitulation may be legitimately looked for in epembryonic as well as embryonic stages, or that it may be sought in epembryonic stages, even though masked or falsified in embryonic stages. It is true, of course, that some speak of a comparison of *ontogeny* and phylogeny when, judging by the context, they mean a comparison between *embryogeny* and phylogeny. There arises here a question of definition: does the biogenetic law mean that the *ontogeny* is a recapitulation of the phylogeny, or does it mean that the *embryogeny* is a recapitulation of the phylogeny? If we take the general consensus of opinion we shall find for the former definition, and if we take the words of Haeckel, whose statement of the law is the one usually quoted, we shall again find for the former definition. I believe that, as a matter of fact, no one would maintain that the second definition is correct, however much he might forget in his studies to take the epembryonic stages into consideration.

Nor would I create the impression that the embryologists and zoologists have utterly deserted the paleontologists in their support of the recapitulation theory. Several recent papers give considerable aid and comfort to those of us who still believe in recapitulation. I shall introduce here the conclusions of three of these workers, more particularly because it will afford me an opportunity to correct what I hold to be another error of those who oppose the theory.

One of the most interesting pieces of evidence that has recently been adduced in favor of the idea that ontogeny recapitulates phylogeny is to be found in a paper by Griggs on "Juvenile Kelps" (28). It is not my purpose, however, to discuss the very interesting evidence which he has recorded, but rather to quote his remarks on the views of His and Morgan, and his general conclusions. His maintains that the reason why ontogeny seems to recapitulate phylogeny is because the stages in development are, as Griggs paraphrases it, "only the physiologically necessary steps for the formation of the adult body from its earliest stage, which in most cases is the egg." With the ideas of Morgan as expressed in his valuable book on "Evolution and Adaptation" we are all familiar. He holds that organisms repeat in their development, not adult stages, but only embryonic stages of their ancestors. To this idea he has given the name of "repetition."

On this point of the recapitulation of embryonic conditions Griggs makes the following pertinent statements: "In the toothless animals, the whale and the bird, the development of teeth in the jaws is entirely unnecessary * * * it may even be said to hinder the attainment of the adult condition. The same is true of the mammalian gill slits and of most structures which have in the past attracted attention in connection with the recapitulation theory. As the ancestral period when such structures were fully developed in the adult becomes more and more remote, the tendency to inherit them becomes less and less, because of the cumulative impulses given to the heritage by the nearer ancestors. Consequently they are successively less and less developed. Any gradual loss of inheritance can, in the nature of the case, take place only from the mature condition backward toward the beginning of the life cycle; otherwise we should have adult structures with no ontogenetic history. Therefore we can understand why it is that in many cases only the embryonic stages of ancestral history persist in the ontogeny." In a foot note he says: "The cutting off of end stages in the development of organs has

given rise to the idea that the adult stages are 'pushed back into the embryo.' Such a misconception easily arose from the loose language in which the facts have often been expressed. Thus the embryogeny will be gradually shortened by the omission of more and more of the superfluous ancestral stages; and it will tend finally to retain only such stages as are necessary to the attainment of the adult form." Morgan and His, he maintains, have confused morphology and physiology. "The recapitulation theory has nothing to do with physiology; it is purely a matter of morphology."

In conclusion Griggs says: "Taking all the evidence into consideration, it seems to the writer that we are bound to conclude that though organisms are subject to adaptations at any stage of their life cycles and may gradually cut out superfluous stages, yet, except as some such tendency has operated to change the heritage, the development of the individual does recapitulate the history of the race * * * recapitulation must take place if there is any force which tends to make offspring like parent, if heredity is of any importance in moulding the forms of organisms. On the other hand, if there is any variability of transmutation of individuals in stages other than the adult end stages of the life cycles, the recapitulation cannot be perfect, but must be marred at every stage where secondary change has taken place." I shall return later to some of the points raised by Griggs in the above statements.

Another eminent worker, Dr. Eigenmann, says at the close of a paper on the eyes of the blind vertebrates of North America (20): "We have seen in the preceding pages that the foundations of the eye [of *Amblyopsis*] are normally laid, but that the superstructure instead of continuing the plan with new material, completes it out of the material provided for the foundations, and that in fact not even all of this (lens) material enters into the structure of the adult eye. The development of the foundations of the eye is phylogenic, the stages beyond the foundations are direct."

The third writer, Dr. Zeleny (64), in his paper on "Compensatory Regulation," in a discussion of the development and regeneration of the opercula in serpulids, says that the morphologic series is so complete as to make sufficient ground for the conclusion that the opercula arose in the course of phylogeny as modified branchia. The ontogenetic series, he says, *corresponds very closely with the probable phylogenetic series.* Speaking of the regeneratory development he says: "The course of re-

generatory development is characterized by great condensation and directness of the development. There is no trace of the branchial stage, and the development of the two rows of processes of the terminal cup does not follow the ontogenetic order."

His final conclusion is as follows: "The data furnished, therefore, by the opercula of the serpulids give a fairly close agreement between the ontogenetic stages and the probable phylogenetic ones as determined by the usual criteria. The regeneratory development, however, follows a course which may be modified by the character of the operation that leads to the regeneration." By the "usual criteria" he means morphology, etc., so that he cannot be accused of the *circulus vitiosus*.

Those who wish to review the detailed evidence given in the above papers, bearing on the theory of recapitulation, will, of course, consult the original papers. My main reason for quoting them is, as stated above, because of their bearing on what seem to me to be grave errors in the reasoning of His, Morgan and Montgomery and others who have adopted similar views. The error seems to me to be, as pointed out by Griggs, in the confusion of morphology and physiology. The adult characters that are supposed to be recapitulated in the ontogeny, as well as the characters in ontogeny that are supposed to represent them, are morphological characters solely. It matters not what new function they may have come to serve, nor by what physiologic process they have come to make their appearance in the recapitulating organism. The confusion arising from this source colors all the argument of Montgomery, in which he endeavors to prove that new specific characters must have some representation in the ovum—a view which we must certainly agree with—and that therefore "the whole row" of cells from the ovum to the adult must be different. We grant that "The whole row" *is* different in some way, physiologically different, different in its play of energies; but it may conceivably be morphologically identical up to the very point where the new character is added. It is just as easy to conceive that the energy, or whatever we choose to call it, that is at a certain stage in development to produce a certain rib or spine or color-band on the shell of a gastropod, may be handed through the row of cells reaching up to the given stage, without producing a single recognizable morphologic change in the row, as compared with the individual that is not to possess the new character, as it is to conceive the opposite. The argument for the one view is just as certainly *a priori* as the argument for the other view. It

is also perfectly conceivable that the morphology of the *individual cells* in the row might differ after the acquisition of the new character (in so far as this assumption is required by recent cytological studies), and yet not a single organ or part of the organism be different up to the stage in ontogeny when the new character appears. Unless, therefore, a change in the energies of the cells *inevitably necessitates* a change in the morphology of all the cells or of all the organs which they compose, the argument of Montgomery proves nothing.

As to the argument of His and others, that the supposedly ancestral stages are merely the physiologically necessary stages in the development of the individual; it again, as Griggs points out, confuses morphology with physiology, and is open to the further objection that it is directly opposed to the facts. Why, for example, should the condition of perfect blindness, with complete loss of all the essential structures of the eye, be attainable only by the round-about way of first developing the foundations of a normal eye? Why should a serpulid be able to regenerate a perfect operculum in a manner entirely different from, and even opposed to the ontogenesis of the organ, if there is any physiologically necessary way in which that particular individual or that particular organ must develop? The thing that makes it necessary for development to take a certain course in a given individual is the fact that the development has taken that same course in the ancestors. This species of coercion may, to be sure, be relaxed, and the development take some other course, but it is usually relaxed with extreme slowness, and after many generations have passed.

If inheritance were perfect, the individual would take exactly the same course in development as its ancestors. That it does not do this in all cases is, as Griggs points out, a more remarkable fact than that in other cases it should follow the ancestral mode of development so closely. Griggs explains the loss of inheritance as due to a progressive condensation of the ontogeny by the "omission of more and more of the superfluous ancestral stages." This is the well-known law of acceleration or tachygenesis. Like most embryologists, however, he misconceives the law, as shown by the foot-note quoted above. Embryologists are especially prone to limit the law of acceleration in development to the skipping or omission of steps, and the consequent shortening of development. This is not in keeping with the views of Hyatt, who first definitely formulated the law; and, as all paleobiologists know, it is not in keeping with the

facts. Hyatt (31) says: "All modifications and variations in progressive series tend to appear first in the adolescent or adult stages of growth, and then to be inherited in successive descendants at earlier stages according to the law of acceleration, until they either become embryonic or are crowded out of the organization and replaced in the development by characters of later origin." A more concise statement of the law is as follows: "The substages of development in ontogeny are the bearers of distal characters in inverse proportion and of proximal characters in direct proportion to their removal in time and position from the protoconch, or last embryonic stage" (31).

According to the definitions just quoted, acceleration involves not only the omission of characters, in some cases (and this is the only sort of acceleration that most embryologists seem to recognize), but it involves also condensation without omission, by crowding more into a given portion of the ontogeny, or again by "telescoping" of characters, as Grabau (25) calls it, so that characters that originally appeared in succession, come to appear simultaneously. In other words acceleration may be by *elimination*, by *condensation*, without change in the order of appearance of characters, or, third, by *telescoping*. The latter is condensation with change in the order of appearance, or as commonly expressed, unequal acceleration. It is probable that paleobiologists have erred in giving too much emphasis to the principle of earlier inheritance, involved in the law, just as embryologists and morphologists have erred in entirely neglecting this phase of inheritance. As conceived by the paleobiologist, the law of acceleration is an explanation of recapitulation, as well as an explanation of the failure to recapitulate.

Another factor in inheritance has been given the name of retardation by Cope (15). By the operation of this factor, characters that appear late in the ontogeny may disappear in descendants because development terminates before the given character is reached. In this way, it is conceived, the ontogeny may be shortened and simplified, and many ancestral characters lost entirely. The result of the continued operation of retardation would be retrogression. That is, the given form, if it continued to repeat the remoter ancestral stages in the early part of its ontogeny, and continued at the same time to drop off the later ancestral stages, by failing to proceed far enough in its development, would ultimately come to resemble the remote rather than the nearer ancestors. Manifestly the retarded forms do not recapitulate the lost characters, so

that here, also, as in the omission of characters in the earlier stages of ontogeny, the heritage is incomplete.

Of the complications of inheritance that arise from larval adaptations, intra-uterine adaptations, and special adaptations arising in later life, I shall not speak. All of these have been repeatedly discussed (see for example Smith 57), and are well understood. Against all of these the paleobiologist must be on his guard. All of these factors tend to make the parallelism between ontogeny and phylogeny inexact, as long ago pointed out by Cope (15). Yet in spite of the operation of these factors, the cases in which there is clear evidence of recapitulation are so numerous, and so well known to the paleobiologist, that were it not for the continually reiterated statements of certain embryologists that there is no such thing as recapitulation, I should hesitate to again point them out. I shall now take up the evidence according to the groups of organisms in which it has been ascertained; and I once more remind the reader that most of this evidence applies to the epembryonic and not to the embryonic stages.

## II.

*Cephalopoda.*—The only existing representative of the great group of Tetrabranchiata, the class to which nearly all of the fossil cephalopods belong, is the *Nautilus.* The genus *Nautilus* is a striking example of the persistence of a primitive type. It belongs to the more primitive branch of the tetrabranchs, from which, according to all the evidence, the marvelously complex ammonities, on the one hand, and the modern naked cephalopods are descended. Nautilus is the only tetrabranch of which the entire ontogeny, including the embryonic stages, is known.

This lack, however, in the case of the fossil genera is not as serious as might be supposed, for the reason that even in these ancient forms all of the growth stages from the latest embryonic (phylembryonic) stage to the adult are preserved in every complete individual shell. An inspection of the *Nautilus* shell makes this at once apparent, for the earlier stages of the shell are surrounded and protected by the later, and no part of the shell is lost or resorbed. In the straight and loosely coiled shells only, such for example as *Orthoceras, Cyrtoceras, etc.*, is the case different; and even here, barring injury, or the dehiscence of the earlier chambers, every post-embryonic stage is preserved. From a study, therefore, of a single shell, we are able to make out perfectly all of the epembryonic de-

velopment in that part of the organism that was most vitally affected by the environment, and which must therefore indicate most perfectly the lines along which the evolution proceeded.

If the initial portion of the shell of *Nautilus* be examined, it will be found to be characterized by a scar or cicatrix. In the same region of the shells of ammonites and some Nautiloidea (*Orthoceras*), instead of this cicatrix, there is present a minute, bulbous or bag-like shell, attached to the apex of the shell proper. If in the case of *Orthoceras*, as shown by Hyatt (31), this bulb, or protoconch be broken away, there is exposed a scar (cicatrix) precisely similar to that of *Nautilus*. The initial shell or protoconch is therefore substantially the same in all of the Tetrabranchiata, and is supposed to point to a "septa-less and chamberless form similar to the protoconch" as the common ancestor of these two great divisions of the Tetrabranchiata; and possibly, as Hyatt suggests of the Cephalopoda, Pteropoda and Gastropoda (31). The protoconch represents the latest of the true embryonic stages, namely the phylembryo.

Succeeding this early stage are the stages of the shell proper.[1] In *Nautilus* the early nepionic portion of the shell, which includes the formation of the first three septa, is only slightly curved (cyrtoceraform). Up to the stage of the formation of the second septum, the shell is in fact nearly straight (orthorceraform). The first septum has an apically directed caecum, and the second septum an apically directed closed tube, the closed apical end of which fits into the caecum of the first septum. This tube is the beginning of the siphuncle. Since the tube fits closely into the caecum, the two together form a continuous tube, in which the apical end or bottom of the siphuncular tube forms a partition or septum, so that as Hyatt points out, the resemblance "of this early stage to the adult structures of *Diphragmoceras* becomes perfectly clear." (31)

In the later nepionic stages (i. e., after the formation of the third septum) the shell is rather sharply bent (the gyroceran curve), so that near the close of the first volution the whorl is brought back into contact with the apex of the conch. This manner of growth results in leaving an empty space or *umbilical perforation* between the two halves of the first volution. In the ancient coiled Nautiloidea there appears at the beginning of this (neanic) stage, when the whorls come into contact, a de-

[1] The stages from this point on are termed by Hyatt (31), and following him by practically all paleobiologists at the present time, the *nepionic*, *neanic*, *ephebic* and *gerontic* stages; meaning respectively, the infantile, youthful, mature and old age stages of growth.

pression or groove in the dorsum of the whorl, where it rests against the venter of the preceding whorl. This is the *impressed zone*. In the modern *Nautilus*, however, this furrow or impressed zone begins in the early nepionic stage, *before the whorls have come into contact*. This occurs also in the nautilian shells of the Carboniferous, Jurassic, Cretaceous and Tertiary.

Of this truly remarkable feature of cephalopod development, Hyatt says: "When one ascends in the same genetic series to the more specialized nautilian involved shells this purely acquired character becomes, through the action of tachygenesis, forced back, appearing as a rule in the nepionic stage before the whorls touch. It is therefore, in these forms entirely independent of the mechanical cause, the pressure of one whorl upon another, which first originated it. One need only add that this configuration of the dorsum is never found in the adults of any ancient and normally uncoiled shells, so far as I know, nor so far as have been figured." (31)

Without reviewing any of the further interesting details of the ontogeny of *Nautilus*, enough has been said to make it evident that if there is any truth in recapitulation, the development of *Nautilus* would indicate (disregarding the protoconchal characters) an ancestral line that contained, first straight or slightly arched, then loosely coiled, and finally closely coiled shells, and that the earliest of these possessed a septate siphuncle. That the geological series of shells indicates the same thing every paleontologist knows perfectly well. The development of *Nautilus* also affords one of the most perfect illustrations of the law of tachygenesis, in the earlier inheritance of the impressed zone, known in the whole animal kingdom.

One further illustration, from the Cephalopoda, of the parallelism of ontogeny and phylogeny must suffice. This illustration is drawn from the genus *Placenticeras*, one of the complex Ammonites of the Cretaceous. The development of this genus has been beautifully worked out by Professor J. P. Smith (58). The species *P. pacificum* comes from the Chico formation of the Upper Cretaceous. The following account applies to the development of this species and is drawn from the paper by Smith, cited above.

The earliest shelled stage was probably passed before the animal was hatched. This is the protoconch or phylembryo. It is a smooth, oval, bulbous body, similar to that of all the later ammonites. It probably rep-

resents an "adaptive form, due to life in the egg, and does not represent any ancient ancestral genus, for none of the early cephalopods were shaped like this."

"With the formation of the first septum, the young ammonite has taken its place among the chambered cephalopods, and has become, for the time being, a nautiloid, although it is not possible . . . . to correlate it with any special genus. . . . . The first septum . . . . is nautilian in character, but the siphuncle begins inside the protoconch with a siphonal knob, or caecum, and the protoconch itself is calcareous. These are two characters that the nautiloids even to this day, have never yet acquired. . . . . We have in this stage ammonite characters pushed back by unequal acceleration [telescoping], until they occur contemporaneously with more *remote* ancestral characters."

There is no sign of an umbilical perforation as in the *Nautilus*, described above, a fact which again shows the degree of acceleration of these ammonites.

With the second septum the ammonite characters are assumed. The shell at this stage is "distinctly goniatitic," but also possesses characters introduced by acceleration, that belong to later genera. The evidence indicating the goniatitic as well as later stages to be mentioned, is mainly the character of the suture lines. "At about five-eighths of a coil . . . . the larva has reached a stage correlative with the goniatites of the Upper Carboniferous." This stage is quickly passed, and the goniatitic characters are lost and characters transitional to the ammonite stage make their appearance. "At one and one-twelfth coils the shell is transitional from the glyphioceran stage to what resembles closely the genus *Nannites* of the Trias." In regard to this stage Smith says: "If it had not been said that this was a minute shell taken out of an older individual, any paleontologist would refer it without hesitation to the Glyphioceratidæ, and probably to . . . . *Pronannites*, of the Lower Carboniferous." This stage lasts about one-half revolution.

In the neanic stage, at one and seven-twelfths coils, the shell resembles very strongly *Cymbites*, or some related genus of the Lower Jurassic. The first signs of shell sculpture occur in this stage. In the next stage the sculpture becomes stronger, and the shell assumes a decidedly aegoceran appearance. From two up to two and one-quarter coils, the shell resembles in most respects the stock to which *Perisphinctes* belongs, and this is accordingly called the perisphinctes stage. During this

stage the sides of the shell become more flattened, and the abdominal shoulders squarer, the varices frequent, and strong intermediate ribs appear on the sides and abdomen.

In the next (*Cosmoceras*) stage "the ribs no longer cross the abdomen, but end in tubercles on the abdominal shoulders, forming well defined shoulder keels, with a furrow between them." Near the beginning of the fourth coil the ribs are reduced to mere faint undulations and fine sickle-shaped striae on the sides of the umbilicus, while the external tubercles become almost obsolete, forming mere notches on the continuous abdominal keels. Specific characters begin to appear here. This may be taken as the beginning of the *Hoplites* stage. The septa have not reached the complete development of the genus.

The umbilical knots begin at this stage, and growing stronger, become a characteristic feature of the adult *Placenticeras*. "*Placenticeras pacificum* at this stage is wholly unlike *P. californicum*, with which it is associated, being much more compressed and discoidal, with narrow abdomen, flatter sides, much less distinct sculpture, and narrower umbilicus, although in the earlier adolescent periods both species are very much alike." The shell passes from this stage by gradual changes into the adult *Placenticeras*.

Professor Smith's conclusions are of especial interest. He says: "The development of *Placenticeras* shows that it is possible, in spite of dogmatic assertions to the contrary, to decipher the race history of an animal in its individual ontogeny."[1]

[1] For further illustrations of recapitulation among the Cephalopoda, the student should consult the following papers: Branco, W., Beiträge zur Entwicklungsgeschichte der fossilen Cephalopoden, *Paleontographica*, vols. xxvi, xxvii, 1879, '80. Buckman, S. S., Monograph of the Inferior Oolite Ammonites, *Paleontographical Society*, 1887-'96. Hyatt, A., Paralellism of the individual and the order among tetrabranchiate Mollusks, *Mem. Bos. Soc. Nat. Hist.*, vol. i, 1866; Fossil cephalopods of the Museum of Comparative Zoology, *Bull. Mus. Comp. Zool.*, vol. iii. 1872; Genesis of the Arietidæ, *Smithsonian Contr. to Knowl.*, vol. xxvi, 1889; Phylogeny of an acquired characteristic, *Proc. Am. Phil. Soc.*, vol. xxxii; Cephalopoda, in *Text Book of Paleontology* by Zittel (Eastman trans.), 1899. Hyatt, A., and Smith, J. P., Triassic cephalopod genera of North America, *U. S. Geol. Surv. Prof. Paper* No. 40, 1905. Karpinsky, A., Ueber die Ammoneien der Artinsk-Stufe, *Mem. Acad. Sci. Imp. St. Petersburg*, vol. xxxvii, No. 2, 1889. Neumayr, M., Die Ammoniten der Kreide und die Systematik der Ammonitiden, *Zeitschr. der Deutch. Geol. Ges.*, 1875; Ueber unvermittelt auftretende Cephalopodentypen im Jura Mittel-Europas, *Jahrb. d. K. K. Geol. Reichs. Wien*, vol. xxviii, 1878. Smith, J. P., The development of Glyphioceras and the phylogeny of the Glyphioceratidæ, *Proc. Calif. Acad. Sci.*, (3) *Geol.*, vol. i, 1897; The Development of Lytoceras and Phylloceras, *Ibid.*, 1898; Larval stages of Schloenbachia, *Jour. Morphology*, vol. xvi, 1899; The Carboniferous Ammonoids of America, Monog. U. S. G. S., No. xlii, 1903. Würtenburger, R., Studien über die Stammgeschichte der Ammoniten, Leipzic, 1880.

*Pelecypoda.*—The classic memoir of Jackson (32) on the phylogeny of the Pelecypoda brings together numerous illustrations of recapitulation among the members of this class of animals. Jackson's conclusions are well-known, and I shall therefore review them very briefly.

From a study of a large number of genera representing widely divergent members of the Pelecypoda, Jackson concludes that there is present throughout the group an embryonic shell, which he calls the "prodissoconch" (a term correlative with the term protoconch of the Cephalopoda and Gastropoda), and which is a simple bivalved, equivalve shell. At this (phylembryonic) stage of development there are two adductor muscles, even in genera in which the adult have only one adductor. That is, the prodissoconch is dimyarian even though the adult animal may be monomyarian. In the Aviculidæ and their allies (*Ostrea*, *Avicula*, *Perna*, *Pecten*, *Plicatula*, *Anomia*) the prodissoconch very closely resembles in form the primitive genus *Nucula*. The anatomical characters of the prodissoconch also bear out this resemblance. It is therefore inferred that some such type as *Nucula* is the primitive ancestor of the Aviculidæ, and possibly of the Pelecypoda. The paleontological and anatomical evidence supports this conclusion.

We have here, then, in the Aviculidæ and their allies, a group of monomyarians, some of them, as *Ostrea*, *Plicatula*, and *Anomia*, of very aberrant form, the representation in the ontogeny of a dimyarian stage, which, from all the evidence, actually characterized the adults of the ancestors of the group. Whether or not *Nucula* is the actual ancestor of this group of pelecypoda, it is quite certain that the earliest pelecypods were of the same general form as the prodissoconch, and that they were dimyarian.

In the same paper Jackson has shown in a masterly manner that the ostreaform shape of the shell, which characterizes many more or less widely separated genera of pelecypods, is due to "the mechanical conditions of direct cemented fixation." These ostreaform shells are very variously derived, and should, if there is anything in the theory of recapitulation, each show in the young stages, before the valves have become fixed, the distinctive adult characters of its particular ancestor. In this case we are relieved from the danger of arguing in a circle by the fact that the genetic relations of most of the forms are fairly well known from lines of evidence other than the ontogeny. The following specific cases cited by Jackson are of especial interest.

*Mulleria lobata*, a member of the Unionidæ, "is so remarkably like an oyster (in the adult) that it has been called the fresh-water oyster. In the monomyarian adult . . . . the shell is rough and irregular with a deep attached and flattish free valve, and a specimen in the Museum of Comparative Zoology is indistinguishable in shape from forms commonly found in *Ostrea virginiana*. . . . . The young shell of *Mulleria* . . . . is Anodon-shaped, equivalvular and dimyarian as described by authors."

*Hinnites* is another genus which has the ostreaform adult. "In the young it is free and pectiniform, but in the adult . . . . so close is the likeness to an oyster that in the synonomy of the genus it has been named *Ostrea* and *Ostracites*." In *Hinnites cortesi* of the Tertiary, in the neanic stage, the right valve is purely pectiniform. "It has the well-developed ears, deep byssal sinus, and an evenly plicated shell which at this stage is nearly or quite equivalvular." With the period of attachment a most marked change in the valves takes place and the adult becomes deeply concave (in the right attached valve) and highly ostreaform. The byssal notch is filled up and "completely wiped out of existence."

In genera such as *Ostrea* and *Plicatula*, where fixation takes place at the close of the prodissoconch stage, the succeeding stages give very little indication of the ancestry, owing to the extensive modification of the shell as soon as fixation takes place. According to Dall *Ostrea* is derived from the Pteriidæ.

*Spondylus* is another genus in which cementation has caused extensive modification of the valves in the adult. Fixation takes place at the close of the nepionic period. Therefore this genus may be expected to afford some evidence of recapitulation. The first nepionic stage of *Spondylus* is decidedly pectiniform. It has a long hinge-line and a deep byssal sinus. After fixation, in the first stages of irregular growth, the byssal notch is soldered over, and eradicated in a manner similar to *Hinnites*.

Another illustration of recapitulation among the Pelecypoda is the case of *Pecten* itself. Of this genus Jackson says: "In the development of the modern *Pecten* we find in the first stages of dissoconch growth a form of shell . . . . presenting characters which make it referable in ancestral origin to *Rhombopteria*, a member of the true Aviculidæ, later succeeded by a growth . . . . bearing marked features referable in origin to an ancestral genus *Pterinopecten*. . . . . Still later a stage

exists . . . . which is referable in its inherited form to *Aviculopecten*, and finally the true *Pecten* features characteristic of the adult . . . . are established. The geological sequence of these several groups is in the order indicated by the development of *Pecten*. We have, therefore, a clear case of the ontogeny of an individual illustrating the phylogeny of the group."

*Gastropoda.*—For studies of the Gastropoda in which growth stages have especially been taken into consideration we are indebted chiefly to Grabau (22, 23, 24, 25) and Burnett Smith (53, 54, 55, 56). My illustrations of recapitulation among the members of this class will be drawn, therefore, from the writings of these two authors.

It is commonly known that the apical whorl of the gastropod shell may differ materially from the succeeding portions of the shell (conch), being smooth and without ornament in cases where the conch is highly sculptured, or in some forms, as *Acmaea* and *Crepidula*, being coiled, although the adult shell is patelliform and non-coiled. To this apical whorl the name "protoconch" has come to be applied, a name which, as we have already seen, is also applied to the embryonic shell of the Cephalopoda. Grabau (22) has suggested the use of the name "protorteconch" in place of protoconch for the initial shell of the gastropods.

The protoconch of the existing Gastropoda is more variable than that of the Cephalopoda, as would be expected from the highly specialized nature of most of the extant representatives of the class. In most cases there is no definite line of demarkation between the protoconch and the conch, but in a few cases, as in *Fusus*, etc., the "end of the protoconch is strongly marked by the existence of a pronounced varix and an abrupt change of ornamentation." (22) "The early whorls of the protoconch . . . . are smooth rounded coils of the type found in adult *Natica*. . . . . In the majority of cases the initial whorl is minute, while the succeeding ones enlarge gradually and regularly. In some types the initial whorl is large and swollen. . . . . This type of protoconch has been termed 'bulbous' by Dall (19). The naticoid form of protoconch is in general umbilicated, and it is probable that at least the earlier portion of the protoconch is umbilicated in the majority of gastropods.

"From the characters of the initial whorls of the protoconch we may argue that the radicle of the coiled gatropods must have been a naticoid type with a well-marked umbilicus. Such a type is found in *Straparollina remota* Billings, one of the earliest coiled gastropods of the Etcheminian

or Lower Cambrian of the Atlantic border province of North America. That it is not the most primitive type of gastropod is suggested by the consideration that the earliest stage . . . . of the protoconch is not coiled, but rather cap-shaped like modern *Patella*. Such primitive types are found in Lower Cambrian species which have variously been referred to *Platyceras*, *Scenella*, or *Stenotheca*, owing to the want of sufficient characteristics to define their exact relations." (22.)

From the above it appears that the early protoconch stages indicate an ancestor of the simple, smooth shelled, umbilicated type exemplified by *Straparollina*, and that this is actually the only type of coiled gastropod characteristic of the basal Cambrian. It is also likely from paleontological evidence that the very earliest type of gastropod possessed a conical or cornucopia-shaped shell of the *Scenella* type.[1] Such an ancestry is, according to Grabau, suggested by the cap-shaped earliest stage of the protoconch.[2]

One of the most completely worked-out cases of recapitulation among Gastropoda that has come to my knowledge is that of the races of *Athleta petrosa* Con. and its allies. The phylogeny of this group of gastropods has been very fully studied by Burnett Smith (54), from whose paper the following account is drawn.

[1] Sardeson (50) suggests that the gastropod ancestor was an "asymmetrical long conical shell" of the pteropod type. He may be right, but even so, I do not see that his conclusion would in the least invalidate the conclusions of Grabau in regard to the phylogenetic significance of the protoconch, although Sardeson seems to think so. Grabau says very plainly that the coiled shell is probably not the most primitive type of shell, and he points out the fact (quoted above) that the initial portion of the protoconch is cap-shaped and may indicate some such remote ancestor as the Cambrian forms referred to the genera *Platyceras*, *Stenotheca*, and *Scenella*. Whether this patelliform ancestor was in turn derived from a long conical shell, or whether on the other hand the coiled type of shell was derived directly from the "long conical" shell without the mediation of a patelliform ancestor, does not materially affect the conclusions that at a very remote time a coiled gastropod radicle was established from which practically all modern gastropods were derived. To my mind the conclusion that the ultimate ancestor of the Gastropoda was a "long conical" shell is by no means established.

[2] Burnett Smith (55) concludes from a study of the Tertiary species of the genus *Athleta* that "we can say for this restricted normal group at least that the apex is not only a variable feature, but the most variable feature which the shells furnish." In a footnote he says "The author is thoroughly convinced that the features of the apex must be used in classification with great caution." The variations which he cites in this and other papers (54, 55, 56) seem to be chiefly in the size of the protoconch, and the degree to which acceleration has caused conchal characters to appear in the later protoconchal stages. His caution, however, in regard to the classificatory value of the protoconch, should put students of the gastropods on their guard against a too free use of this portion of the shell in the establishing of genera.

The species under consideration occur in the Gulf Eocene, extending nearly throughout it. They have heretofore been referred to the genus *Volutilithes*, but are placed by Smith (55) in the genus *Athleta*. Smith states that the material at his disposal was very complete, and enabled him to study large series of individuals, very carefully collected with reference to horizon. The stratigraphy of the formations from which they came is also well understood. These favorable conditions of study, it may be remarked, are especially important in the present connection, because they enabled Smith to trace out the evolution of the forms practically continuously from zone to zone, without being chiefly dependent on ontogeny for indications of their relationships. Another fortunate circumstance is the fact that this author is disposed to use the evidence from ontogeny with the utmost discretion, everywhere checking it by an appeal to the morphological and geological series.

In the forms under consideration, the first two or three whorls are smooth and rounded, constituting the smooth or protoconchal stage. "The first ornamental feature to appear on the smooth, rounded whorl is the transverse rib, that is, a slight elevation of the whorl which runs across it from suture to suture. These early ribs are invariably curved slightly, and each one is simple and uniform from suture to suture. The curved ribs persist as a rule for about a quarter or a half of a whorl, or even for a much less space. . . . . The curved rib stage . . . . has been found in every species and race dealt with in this paper. The curved ribs, after about one-third of a whorl, change abruptly into the straight ribs of what has been designated the cancellated stage."

"The cancellated condition is found more or less well developed in all the different races. In the primitive races it may persist as a constant feature to the end of the individual's life; but in most forms it covers only a few whorls and is more variable than the preceding curved rib stage." The end of the cancellated stage is much less definite than the beginning. It is followed by the "spiny stage." In this stage the shoulder tubercle is sharp and spine-like. Other tubercles have disappeared, and this portion of the shell is therefore no longer cancellated. Succeeding the spiny stage, there may be a senile stage.

In the base of the Eocene at Matthew's Landing, Alabama, occurs a species, *Athleta limopsis*, which from its primitive characters, and its position at the base of the Eocene, Smith regards as the ancestor of the races and species which he deals with in his paper. This form presents

no stages later than the cancellated stage. There is also very little individual variation. Associated with *A. limopsis* is the species *A. rugatus*. In its earlier stages this species very closely resembles *A. limopsis*, but "differs radically . . . . from that form with the progress of its ontogeny." In its later whorls it presents evidence, though not extreme, of senility. It has no spiny stage.

The next species *A. petrosa*, represents an assemblage of races connected by many intergrading forms. These races range upward from the Nanfalia beds to the Jackson beds of the Eocene. Several of them are senile races, and in the adult strikingly different from the ancestral form, *A. limopsis*. Smith says, however, that the young of all the races "are remarkably uniform and constant. The early whorls indicate clearly that they are all descended from a cancelated ancestor, and bear a strong resemblance . . . . to the characters of *A. limopsis*." Some of the senile races of *petrosa* are profoundly modified in the adult, as for example, the Hatchetigbee race, derived from the main stock through the Bell's Landing and Wood's Bluff races. Yet their derivation from the main stock is shown by intermediate forms, and the young of the terminal races greatly resemble the ancestral form. In the Jackson race, which is the terminal member of the main stock, the last two whorls are spiny, and the last whorl shows some senile characters at its close. "This race shows a regular and even ontogeny." Acceleration has carried the curved rib stage back to the beginning of the third whorl, whereas in the ancestral *A. limopsis* this stage begins near the close of the fourth whorl.

Smith has graphically expressed the main developmental and phylogenetic changes in the following diagram:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *A. limopsis.* Matthew's Landing race.. | ... | ... | A | B | ... | ... | ... | C | .... | .... | .... | Lower Eocene. |
| *A. petrosa.* Gregg's Landing race.... | ... | A | ... | B | ... | C | .... | ... | D and I | D and I | .... | E Slight. |
| *A. petrosa.* Jackson race ........... | A | ... | B | ... | C | ... | ... | ... | D | D and E | .... | E never extreme.<br>Upper Eocene. |

In the above diagram the figures across the top stand for the number of the whorl of the shell, and the letters indicate the different ontogenetic stages as follows:

A—Smooth stage.
B—Curved rib stage.
C—Cancellated stage.
D—Spiny stage.
E—Senile stage.
I—Individual variation.

The acceleration of the Jackson race is beautifully brought out in this diagram, and as its correlative, the recapitulation in the earlier ontogeny of the later races, of the adult characters of the ancestral race. The individual variations may occur on any part of the shell, but usually follow stage C.[1]

*Brachiopoda.*—Among the members of this class there is a wealth of illustrations of recapitulation. I can only select a few cases that have been worked out in such a way that the relationships of the forms are indicated by the morphological and geological series as well as by the ontogeny. The pioneer student of the correlation of ontogeny and phylogeny among the brachiopods was Beecher, whose refined researches in paleobiology have never been excelled and rarely equaled.

The developing brachiopod, in the later embryonic stages, secretes in the mantle on opposite sides of the body two shell plates, which by peripheral growth ultimately meet at the edges and form the initial shelly investment of the animal. This initial shell to which Beecher has given the name "protegulum" (6) is of very simple form, consisting substantially of two convex plates of semicircular plan, gaping at the posterior straight edges. Through this gap between the two valves the pedicle (organ of attachment) projects. At first the pedicle occupies the full width of the valves, but subsequent peripheral growth of the shell with-

[1] For additional studies of the gastropoda from the developmental standpoint see the following: Koken, E., Ueber der Gastropoden vom Cambrium bis zur Trias. *Jahrb. für Mineral. Geol. u. Pal.*, 1889, Beil. Bd. vi. Linden, Gräfen M. von. Die Entwicklung der Skulptur und der Zeichnung bei den Gehausschnecken des Meeres, *Zeitschr. Wiss. Zool.*, vol. lxi, 1896. Grabau, A. W., Studies of Gastropoda II, Fulgur and Sycotypus, *Am. Nat.*, vol. xxxvii, 1903; Phylogeny of Fusus and its allies, *Smithsonian Miscell. Coll.*, vol. xliv, 1904; Studies of Gastropoda III on Orthogenetic variation, *Am. Nat.*, vol. xli, 1907. Smith, Burnett, Phylogeny of the species of Fulgur with remarks on an abnormal specimen of Fulgur canaliculatum and sexual dimorphism in Fulgur carica, *Proc. Acad. Nat. Sci. Phila.*, vol. liv, 1902; Senility among Gastropods, *Proc. Acad. Nat. Sci. Phila.*, vol. lvii, 1905; Phylogeny of the races of Volutilithes petrosus, *Proc. Acad. Nat. Sci. Phila.*, March 1906; A new species of Athleta and a note on the morphology of Athleta petrosa, *Proc. Acad. Nat. Sci. Phila.*, May, 1907; A contribution to the morphology of Pyrula, *Proc. Acad. Nat. Sci. Phila.*, May, 1907.

out corresponding enlargement of the pedicle, leaves the latter restricted to a notch (delthyrium) in the posterior margins of the valves, providing the peripheral growth is about equal on all anterior and lateral radii. If the shell growth is greater in the anterior direction, the shell becomes pointed, the pedicle (posterior) end remaining of about the original width. If the shell growth is mainly in the lateral directions, the shell becomes wide, with a long straight hinge, of which the pedicle opening forms a very small proportion. Whatever may be the later growth of the shell, all the earlier stages are preserved, except in cases where the beaks are injured or resorbed by the encroachment of the pedicle in adult and senile stages. The growth of the shell is entirely by additions at the margins or on the inner surface. It follows that the protegulum may in exceptionally well preserved material be seen intact at the beaks of the adult shell. It is often seen at the apices of young shells.

Searching for the phylogenetic significance of the protegulum, Beecher (6) ascertained that certain of the earliest known brachiopods approximate very closely in form to the protegulum, and he selected the genus *Paterina* (*Iphidea*) as the radicle of the class. It has since been shown that *Paterina* is not the most primitive known brachiopod.[1] It is still true, however, that the most primitive brachiopods known are of the same general form and type as *Paterina*, in fact they approximate more closely, if anything, than that genus, to the form of the protegulum. It may be very safely concluded, therefore, from the geological evidence, that the primitive brachiopod was actually of the type indicated by the protegulum.

Beecher says of *Paterina:* "In mature specimens, all lines of growth, from the nucleai shell to the margin, are unvaryingly parallel and concentric, terminating abruptly at the cardinal line. In other words, no changes occur in the outlines or proportions of the shell during growth, through the nepionic and neanic stages up to and including the completed ephebic condition. The resemblance of this form to the protegulum of other brachiopods is very marked and significant, as it represents a mature type having only the common embryonal features of other genera."

Among the Brachiopoda, as among the Pelecypoda there are a number of forms in which the condition of very close fixation or of burrowing has

[1] Walcott (62) seems to reserve this distinction for his genus *Rustella*. Paterina is by him made a subgenus of the genus *Micromitra*. These forms are all placed in the superfamily *Rustellacea*.

given rise to extremely aberrant types. One of the most extreme of these types is the genus *Proboscidella*. The adults of this genus bear a very marked resemblance to the Pelecypod genus *Aspergillum*. In the early neanic stages *Proboscidella* resembles an ordinary *Productus*, from which genus the type is known to have descended. *Orbiculoidea* is a genus originating in the Ordovician, and extending through the Mesozoic. The first stage is paterina-like, the second resembles *Obolella*, the third is like *Schizocrania*, and adult growth brings in the characters of *Orbiculoidea*. The geological order of these genera is the same as the ontogenetic order of *Orbiculoidea*.

Of *Orbiculoidea* and its allies Beecher (7) says: "The early stages of Paleozoic *Orbiculoidea* have straight hinge-lines and marginal beaks, and in the adult stages of the shell the beaks are usually subcentral and the growth holoperipheral. This adult discinoid form, which originated and was acquired, through the conditions of fixation of the animals, has been accelerated in the recent *Discinisca* so that it appears in a free-swimming larval stage. Thus a character acquired in adolescent and adult stages in a Paleozoic species, through the mechanical conditions of growth, appears by acceleration in the larval stages of later forms before the assumption of the condition of fixation which first produced this character."

In the higher genera of the Terebratellidæ, the ontogeny recapitulates the phylogeny with remarkable fidelity, as pointed out by Beecher (7). This example has become classic, so that it is scarcely necessary to repeat the details. I shall give Beecher's conclusions in his own words. He says: "In each line of progression [the austral and boreal subfamilies] in the Terebratellidæ, the acceleration of the period of reproduction, by the influence of environment, threw off genera which do not go through the complete series of metamorphoses, but are otherwise fully adult and even may show reversional tendencies due to old age; so that nearly every stage passed through by the higher genera has a fixed representative in a lower genus. Moreover the lower genera are not merely equivalent to or in exact parallelism with, the early stages of the higher, but they express a permanent type of structure, as far as these genera are concerned, and after reaching maturity do not show a tendency to attain higher phases of development, but thicken the shell and cardinal process, absorb the deltidial plates, and exhibit all the evidences of senility."

Raymond (46) has pointed out a number of interesting cases of recapitulation. The very common and well-known Devonian Spirifer, *S. mucronatus*, has the cardinal extremities in the adult very acute (mucronate), sometimes, indeed, drawn out into needle-like points; while the number of plications may be thirty or more. In the neanic stage these transversely elongated spirifers pass through forms corresponding to the adults of certain Niagara species. The adult of *S. crispus*, corresponds very closely in shape, number of plications, and shell index with these young specimens of *S. mucronatus*.

Shimer and Grabau (51) have shown that in the upper part of the Hamilton series of Thedford, Ontario, there occurs a variety of *Spirifer mucronatus*, which though not mucronate at all in the adult, is "extremely mucronate" in the neanic stage. At this stage also there is evidence of the median plication of the sinus, another charactertistic of the adult of the normal *S. mucronatus*. In the adult of the Thedford variety this median plication has disappeared. The geological and morphological evidence of the derivation of this form of *S. mucronatus* is complete.

I have pointed out an exactly similar case in the variety *senex* of *Platystrophia acutilirata* (16). This variety occurs in the upper part of the Whitewater division of the Richmond series of Indiana and Ohio. *Platystrophia acutilirata*, as is well known, is very mucronate in the adult, resembling in its general outline, *Spirifer mucronatus*. It was in fact at first referred to the genus *Delthyris* (*Spirifer*). The normal form is shown by an unusually closely graded series of intermediate forms to be descended from *P. laticosta*, and it repeats the adult characters of the latter very faithfully in its late neanic stage, becoming always more mucronate as development proceeds. The upper Whitewater form, var. *senex*, frequently has entirely lost, in the adult stages, the acute angulation of the cardinal extremities, so that the lateral and cardinal edges make a right, or nearly a right angle. In the young (neanic) stages of *P. senex*, however, the shell is decidedly mucronate, so that these young shells exactly resemble the normal *Platystrophia acutilirata* of the lower Whitewater and Liberty formations. *P. senex*, it may be remarked, is a well defined form, and its derivation from *P. acutilirata* is beyond question, since it is connected with the latter by every gradation.

Another interesting case of recapitulation among the brachiopods has been worked out with great care by Mr. F. C. Greene (27). In this case also no pains was spared to ascertain the relationships of the various

forms by tracing them continuously from zone to zone, and by a comparison of the morphological characters of the adults. The group studied by Greene is that of *Chonetes granulifer*, from the Upper Carboniferous rocks of Kansas. Here the forms from the higher zones repeat in their ontogeny the characters of forms from the lower zones with great fidelity. The very young stages also recall very forcibly the species of *Chonetes* from the Devonian. *Chonetes granulifer* is also very interesting from the fact that the first hinge-spines appear very much earlier in the ontogeny than is the case in the Devonian species studied by Raymond (46), therefore showing a considerable degree of acceleration of this character during the interval from the Devonian to the Upper Carboniferous.

Other interesting cases of recapitulation among brachiopods have been pointed out by Beecher and Schuchert (12) in the development of the brachial apparatus in *Dielasma* and *Zygospira*.[1]

*Trilobita*.—Studies of the early stages of the development of trilobites have been published by Barrande (3, 4), Walcott (59, 60, 61), Beecher (8, 9), Matthew (39, 40, 41) and others, but for indication of the correlation of the ontogeny and the phylogeny in this class we are almost entirely indebted to Beecher. In his papers on "Larval Stages of Trilobites" (8), and a "Natural Classification of the Trilobites" (9), he has not only pointed out the remarkable way in which characters are recapitulated in this class, but has also proposed what is probably to be regarded as the most perfect example of a phylogenetic classification of a group of organisms, in existence.

The earliest developmental stage of trilobites that has ever been found (barring supposed trilobite eggs) is the larval stage or "protaspis," as it is called by Beecher (8). The protaspis is a minute body of ovate or discoid shape, and about a millimeter in length. This larval stage has

[1] For additional examples of recapitulation among the brachiopods see the following: Beecher, C. E., Studies in Evolution (a series of collected papers), Scribners, 1901. Beecher, C. E., and Clarke, J. M., The Development of some Silurian Brachiopoda, *Mem. N. Y. State Mus.*, No. I, 1889. Beecher, C. E., and Schuchert, C., Development of the shell and brachial supports in Dielasma and Zygospira, *Proc. Biol. Soc. Washington*, vol. viii, 1893. Cumings, E. R., The morphogenesis of Platystrophia; A study of the Evolution of a Paleozoic Brachiopod, *Am. Jour. Sci.*, vol. xv, 1903. Raymond, P. E., The developmental change in some common Devonian brachiopods, *Am. Jour. Sci.*, vol. xvii, 1904. Greene, F. C., The development of the Carboniferous brachiopod Chonetes granulifer, Owen, *Jour. Geol.*, vol xvi, 1908. Buckman, S. S., Homeomorphy among Jurassic Brachiopoda. *Proc. Cotteswold Nat. Field Club*, vol. xii, 1901.

been seen in a sufficiently representative series of genera to make it reasonably certain that it is the common larval type among the trilobites.

It is pretty well established that the eye of crustaceans has migrated from the ventral to the dorsal surface of the cephalon. At an intermediate stage in this process the eyes would appear on the margins of the cephalon. If this has been the history of the eye, the most primitive larvae should show no evidence of eyes on the dorsal surface, and since the eye is on the inner margin of the free cheek, there should be no evidence of the free cheek. This is exactly the case in the youngest larvae of *Ptychoparia*, *Solenopleura* and *Liostracus*, "which are the most primitive genera whose protaspis is known. The eye-line is present in the later larval and adolescent stages of these genera, and persists to the adult condition. In *Sao* it has been pushed forward to the earliest protaspis, and is also found in the two known larval stages of *Triarthrus*. *Sao* retains the eye-line throughout life, but in *Triarthrus* the adult has no traces of it, and none of the higher and later genera studied has an eye-line at any stage of development." This character according to Matthews, is characteristic of the Cambrian trilobites. In its phylogenesis in later trilobites it disappears first from the adult stages, and is finally lost from the entire ontogeny. The eyes appear on the margin of the cephalon in the last larval stage of *Ptychoparia*, *Solenopleura*, *Liostracus*, *Sao*, and *Triarthrus*. In the later genera the eyes are present "in all the protaspis stages, and persist to the mature, or ephebic condition, moving in from the margin to near the sides of the glabella."

According to Beecher (8) "A number of genera present adult characters which agree closely with some of the larval features [of later genera]. The main features of the cephalon in the simple protaspis forms of *Solenopleura*, *Liostracus*, and *Ptychoparia* are retained to maturity in such genera as *Carausia* and *Acontheus*, which have the glabella expanded in front, joining and forming the anterior margin. They are also without eyes or eye-line. *Ctenocephalus* retains the archaic glabella to maturity, and likewise shows eye-lines and the beginnings of the free cheeks (larval *Sao*). *Conocoryphe* and *Ptychoparia* are still further advanced in having the glabella rounded in front, and terminated within the margin (larva of *Triarthrus*). These facts and others of a similar nature show that there are characters appearing in the adults of later and higher genera, which successively make their appearance in the protaspis stage, sometimes to the exclusion or modification of structures present in the most primitive

larvae. Thus the larvae of *Dalmanites* and *Proetus*, with their prominent eyes, and glabella distinctly terminated and rounded in front, have characters which do not appear in the larval stages of ancient genera, but which may appear in their adult stages. Evidently such modifications have been acquired by the action of the law of earlier inheritance or tachygenesis."

*Bryozoa.*—My studies (17, 18) were the first to show that there is in the bryozoan colony a definite recapitulation of ancestral characters, and that in this particular the colony behaves as an individual. This same fact was very clearly pointed out by Ruedemann (47) two years earlier in the Graptolites, and I take pleasure in quoting his very explicit statement. He says: "Furthermore the fact that the thecæ within the same colony show a gradation from phylogenetically older to younger forms, and therefore analogous to the organ of a growing individual, pass through ancestral stages, as, e. g., do the septa of a cephalopod shell, demonstrates how closely the zooids of this colony were united into one organism, and that practically they were more the organs of an individual than the component of a colony. . . . . If the graptolites so closely approached the morphologic value of an individual, it may be expected that, like an individual, the whole colony has its ontogeny and repassed ancestral stages."

My studies, referred to above, brought out the fact that the bryozoan colony begins as a minute hemispherical body, the "protœcium" which is the earliest exoskeletal stage of the first individual of the colony. This protœcium (basal disc) is very conspicuous in the Cyclostomata, and also in the ancient Cryptostomata (as shown in *Fenestella*).[1] It can not be definitely asserted that the protœcium corresponds to any ancestral bryozoan, but the marked resemblance of the zoœcia of some of the ancient *Stomatopora* of the Ordovician to the protœcium is at least very suggestive.

The ancestrula, or first complete individual of the colony, has long been known to present characters more similar to those of ancestral forms

[1] I first used the term protœcium as the designation of the first individual of the colony, and in this sense it would be exactly equivalent to the term ancestrula of Jullien. In a later paper (18) I restricted the term to the basal disc (of Barrois) which is the calicified wall of the metamorphosed and histolyzed embryo in its earliest sedentary stage. Out of this basal disc the first normal individual arises by a process stirctly analogous to budding. In this sense, therefore, the term protœcium is exactly correlative with the terms protegulum, protoconch, prodissoconch, etc.

than the characters of the ephebastic zoœcia (see Nitsche 44, and Pergens 45). I have succeeded in finding evidence (18) that this is true to a notable extent in the ancient *Fenestella*, where the tubular ancestrula bears a striking resemblance to the simple tubular ephebastic zoœcia of the Cyclostomata, from which group there is every reason to believe the Cryptostomata are descended.

It is also pointed out by Nitsche and Pergens *(loc. cit.)* that the earlier budding habit of the colony is similar to ancestral types. In my own studies I was able to show that the early budding habit is very uniform in the most diverse types of Bryozoa, and that it corresponds to the budding habit that prevails throughout the astogeny of the reptant stomatoporas.

In *Fenestella* my studies indicate that the earlier individuals (nepiastic) of the colony are very different from the adult (ephebastic) individuals and are strikingly similar to the ephebastic individuals of certain Cyclostomata that are on morphological grounds, as pointed out by Ulrich (63), probably ancestral. And again, the early neanastic zoœcia of the Devonian fenestellas studied are almost exactly like to the ephebastic zoœcia of the fenestellas of the Niagara series. Unpublished studies indicate that in the Fenestellas of the Upper Carboniferous the neanastic stage is more abbreviated, and that the adult type of zoœcia follows more closely upon the nepionic type.

Dr. Lang of the British Museum has published very interesting studies of the Stomatoporas and Eleids of the Mesozoic (35, 36, 37), and has come independently to exactly the same conclusions as the writer in regard to the development of the colony, and the relations of astogeny and phylogeny among the Bryozoa. He says (35), "The development of the colony is comparable with and follows the same laws as the development of the individual." And again: "Among Jurassic forms of *Stomatopora* and *Proboscina* it has been found that when any given character, such, for instance, as the ratio of the length of the zoœcium to its breadth, is followed from the first zoœcium to the last, that it has a progressive development, or anagenesis, reaches a maximum, or acme, and often may be seen to have a retrogressive development, or katagenesis, in the ultimate branches of the zoarium."

Lang has paid especial attention to the manner of branching in Jurassic stomatoporas. The nearly universal method of branching in the Jurassic members of this group is by dichotomy. This according to Lang may

be by one or other of three types as follows: In type I the two zooecia are separate throughout their entire length, only touching at their bases. In type II they are contiguous throughout their length, and in the intermediate type they are contiguous for part of their length. To a large extent correlated with these types of dichotomy is the angle of divergence of the branches.

In all the Jurassic stomatoporas and in a few proboscinas the first dichotomy is according to type I, and at a very wide angle (180°). The second dichotomy, in the majority of cases, is also according to type I, with an angle of 120°. The next is commonly only 90°, the next 60°, and the next 45°, all according to type I. "In primitive [Jurassic] forms the branching never gets beyond type I with a small angle. In the majority of forms, however, sooner or later the intermediate type of branching comes in, and in a great many forms this type is the final one. In a few cases of *Stomatopora*, and in all *Proboscina*, type II is at some time or other reached, and remains the ultimate form of branching of the zoarium. This sequence namely, Type I—Intermediate type—Type II, is invariably followed." (35).

In primitive *Proboscina* (a genus derived from *Stomatopora*) the first dichotomies are according to type I. "In the typical forms of *Proboscina* the early stages have been so condensed according to the law of acceleration (Tachygenesis), that the first dichotomy is formed on type II. . . . . In the more advanced types of *Proboscina* . . . . the arrangement of peristomes is irregular from the first." This is the typical arrangement for *Berenicea*, a derived genus of which *Stomatopora* and *Proboscina* are the first two terms. It is worthy of notice that while in the Jurassic forms of *Stomatopora* type II is not very common, it is extremely common in the Cretaceous forms.[1]

*Graptolites.*—The beautiful researches of Ruedemann in this group have shown us, as pointed out above, that the graptolite colony closely approaches the morphologic value of an individual, and that, like the individual, it presents definite ontogenetic (astogenetic) stages. Ruedemann (47) applies to the colonial development the terminology proposed by

[1] For studies in the zoarial development of Bryozoa see Cumings, E. R., The development of some Paleozoic Bryozoa, *Am. Jour. Sci.*, vol. xvii, 1904; Development of Fenestella, *Am. Jour. Sci.*, vol xx, 1905. Lang, W. D., The Jurassic forms of the 'genera' Stomatopora and Proboscina, *Geol. Mag.*, Dec. v, vol. i, 1904; The Reptant Eleid Polyzoa, *Geol. Mag.* Dec. v, vol. iii, 1906; Stomatopora antiqua, Haime, and its related Liassic forms, *Geol. Mag.*, Dec. v, vol. ii, 1905.

Hyatt (31). In a later paper, however, he approves the terminology introduced by me, and proposes to call the development of the colony the astogeny (48).

The embryonic stage of the graptolites is represented by the initial portion of the sicula (first zooid), according to Ruedemann; and Holm (29) asserts that the more pointed end of the sicula "corresponds to the original chitinous covering of the free zooid germ or embryo." This initial part of the sicula, according to Ruedemann, holds a position similar to the protoconch of the cephalopod shell.

In part I of his splendid monograph of the Graptolites (48) of New York, at page 530, Ruedemann says: "It has been pointed out in a former publication that not only did there exist in the graptolites ontogenetic growth stages in the development of the individual zooids, . . . . *but the rhabdosomes in toto and in their parts, the branches, seem also to pass through stages which suggest phylogenetically preceding forms.*"

Of the various ways in which these astogenetic stages express themselves, Ruedemann mentions the following: "The original direction of growth of the branches of the Dichograptidæ has been in the approximate continuation of the sicula, i. e., an ascending erect position as long as the rhabdosomes were sessile, on the ground. These became pendant when the graptolites attached themselves in a suspended position to seaweeds, as numerous hydroids do today. To restore to the zooids their original . . . . erect position, the branches began now to recurve . . . . [becoming progressively horizontal, reflexed, reclined and recumbent] . . . . We find now in the majority of the Dichograptidæ with the above cited growth directions of the branches, that the latter still retain their original dependent direction, in the proximal parts in some species, . . . . while in others by the law of acceleration, the dependent proximal direction has already changed into a horizontal one . . . . the change in direction becoming progressively more abrupt as the final direction of the branches becomes reclined . . . . or recumbent. . . . . The branches pass hence, in their development, through different directions representing ontogenetic stages that repeat stations in their phylogenetic development." (48.)

An analogous fact is found in the character of the thecæ. "A comparison of the form of the thecæ of the youngest dichograptid genera . . . . with that of the older and presumably phylogenetically preced-

ing genera . . . . shows that in general the older genera have the more tubular, simpler thecæ, with the less protected apertural margins. It is, hence, apparent that the stolonal or earlier thecæ of the rhabdosomes represent indeed the older types of thecal form." (48.)

*Other Classes.*—The case of the larva of *Antedon* has already been referred to. As pointed out by Bather (1), the stem ossicles of the larval *Antedon* are of a complex and specialized type, and in a general way resemble the stem ossicles of the Bourgueticrinidæ of the Upper Cretaceous. It is held by Bather that the structures of the adult ancestors have been pushed back by acceleration to the larval stages of the existing *Antedon*.

Recapitulation is also shown in the anal plate of *Antedon*. The anal plate appears between two of the radials and on the same level with them. Subsequently it is lifted out from between the radials, and the latter close beneath it. Still later the anal plate is resorbed entirely. That this is the recapitulation of an adult character and not of a larval character, as contended by Hurst, is shown by the fact that the oldest crinoids do not possess the anal plate at all. It appears from paleontological evidence that this plate first appeared above the level of the radials, that it gradually sank down between the two posterior radials, and that at a far later period (at about the close of the Paleozoic) it gradually passed upward again as it does in *Antedon*, and eventually disappeared.

Jackson has shown that there is good evidence of recapitulation among the fossil echinoids (33). In most regions of the echinoid the development is obscured by the more or less extensive resorption, but the plates of the corona may show by their position and number, the course of development. Jackson holds that the introduction of columns of plates, both interambulacral, and ambulacral, in *Melonites*, etc., indicates the stages of growth through which the individual has passed in its development. He shows that two columns of ambulacral plates "may be accepted as the usual characteristic of the whole class, which finds its representative in the majority of the adults, in nearly all young, and in the adult of the simplest and oldest known type, *Bothriocidaris*."

Interambulacral areas originate ventrally in a single plate. Only one genus is known, however, that has a single row of plates in the adult, namely *Bothriocidaris*. This is the simplest known and "perhaps the simplest conceivable echinoid."

In *Goniocidaris* the interambulacral plates of the adult are approximately hexagonal in form instead of pentagonal. "The relative form of the plates in young *Goniocidaris* is almost exactly the same as in the primitive type, *Bothriocidaris*."

"The early stage in which we find a single interambulacral plate, together with two ambulacral plates, in each area is so important that it is desirable to give it a name, the protechinus stage. The protechinus is an early stage in developing Echini, belonging to the phylembryonic period, in which the essential features of the echinoid structure are first evinced. . . . . This protechinoid stage of Echinoderms is comparable as a stage in growth to a similar stage which is expressed in the protegulum of brachiopods, the protoconch of cephalous mollusks, the prodissoconch of pelecypods, and the protaspis of trilobites." (33.)

Miss Smith (Mrs. Alexander Shannon) has shown very conclusively the exact resemblance of the form of the young *Pentremites conoideus* to the adult *Codaster* (52). In *Codaster* the conical form, narrowest at the base and enlarging upward, is maintained throughout life. In *Pentremites* only the early stages of growth have this form, while the adult is broadest at the base and narrowest at the top.

This evidence from development would, according to the theory of recapitulation, indicate that *Codaster* stands in an ancestral relation to *Pentremites*, and it is therefore of importance to the theory that Bather (2) from other evidence has independently reached the same conclusion as Miss Smith in regard to the relationship of the two forms.[1]

Among corals Beecher (5) has worked out the development of *Pleurodictyum lenticulare* and concludes that the first neanic stage, in the manner of growth and the structure of the corallum, is very suggestive of *Aulopora*, and should be given considerable significance." Girty (21) comes to the same conclusion from a study of *Favosites forbesi*, etc.

Bernard (14) has shown that the coral colony in similar fashion to the bryozoan colony and the graptolite colony behaves as an individual. In another paper (13) he has recognized as the first growth stage of the

[1] Bather's conclusion was published in 1900, and Miss Smith's paper in 1906. The latter, however, was not aware of Bather's views as to the relationships of these two forms, so that the conclusions of the two workers, arrived at independently and from different lines of evidence are all the more important and convincing. Bather says in a review of Miss Smith's paper that he considers Pentremites as the "extreme link in the series *Codaster—Phaenoschisma—Cryptoschisma—Orophocrinus—Pentremitidea—Pentremites*."

coral skeleton the "prototheka," or basal cup of the first individual of the colony.[1]

Lang (38) has written a very suggestive paper on growth stages of British species of corals, in which he points out the fact that the ontogenetic stages are repeated in each rejuvenescence (branching?), and suggests that we have here an example of localized stages in development (see Jackson 34). It may be remarked at this point that Ruedemann has also detected localized stages in graptolites (47, 48), and Lang in Bryozoa (36). Lang also, in the paper on corals, concludes that there is recapitulation in the coral genera studied by him, of ancestral characters, and he gives a table illustrating this.[2]

*Summary.*—Paleontologists almost universally accept the theory of recapitulation. Its chief critics have been embryologists. The reason for the difference in attitude is probably to be sought in the fact that the former ordinarily compare epembryonic stages with adult characters of geologically older species, while the latter too often compare embryonic stages with the adult stages of existing species. It is also to be noted that in recapitulation we have to do with morphological and not with physiological characters, and that the row of cells from the egg to the adult may be morphologically the same in two organisms, while being at the same time physiologically different. Until it can be shown that two organisms morphologically different in the adult must of necessity be morphologically different at all stages, the argument of Montgomery, Hurst and others proves nothing.

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[1] The term *prototheka* was proposed simultaneously (January, 1904) by Bernard and myself for the earliest skeletal structure of the coral colony. We have used it, however, in a slightly different sense. Bernard applies it not only to the first individual of the colony, but also to the basal plates or cups of later individuals. I intended to restrict it to the basal cup of the first individual. The references are as follows: Bernard, H. M., The prototheka of the Madreporaria, with special reference to the genera Calostylis, Linds., and Mosleya, Quelch. *Ann. Mag. Nat. Hist.*, Ser. 7, vol. xiii, Jan. 1904. Cumings, E. R., The development of some Paleozoic Bryozoa, *Am. Jour. Sci.*, vol. xvii, Jan., 1904 (footnote, p. 74).

[2] This so-called rejuvenescence in corals appears to be a species of budding, in which the bud is directly superimposed upon the parent. It is fission occurring in a horizontal plane, as suggested by Bernard (14), and the new skeleton is in direct continuity with the old. This is the same idea exactly as that advanced by Ulrich some years ago (63) to account for the diaphragms of the Bryozoa Trepostomata. In the case of the Trepostomata the zoœcium is frequently operculate (ex. *Callopora*), and there is good evidence that the bud grows up through the operculum hence leaving it behind as the floor of the new individual.

In the Cephalopoda, Pelecypoda, Gastropoda, Brachiopoda, Trilobita, Bryozoa, Graptolites, Echinoderms and Corals, examples are pointed out in which there is clear and unmistakable evidence of recapitulation. In most of these cases it is the epembryonic and not the embryonic stages that are the basis of comparison.

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# The Tippecanoe an Infantile Drainage System.

By Wm. A. McBeth.

Streams first come into existence on a recently emerged or uncovered land surface, with enough rainfall to leave a surplus for runoff after the requirements for soil saturation and evaporation have been met. An uplift of part of the sea bottom, the drainage of a lake or the melting of an ice sheet may produce the new surface on which the streams begin their cycle of existence and work.

Most of the streams of northern Indiana are in the youthful stage. They came into being with the recession of the North American Ice Sheet from that part of the State. If parts of the region retained areas of marsh, pond or lake, the location of streams in such areas would be delayed until outlets could be made by the intrenchment of channels by outflowing waters to such depth that the impounded waters would be drained off, when stream lines would be laid out on such newly uncovered lands.

The Tippecanoe river between the abrupt bend on the northeast corner of Pulaski County and Monticello in White County, with its tributaries, furnishes a fine example of extremely young drainage. This section of the river evidently traverses the bed of a former temporary lake which was held in by a moraine at Monticello. Evidence of this lake remains in the sand ridges, some of which seem to be beaches and others dunes numerous in the region. The sudden change in the width and depth of the river valley above Monticello also is significant of such a condition. The valley at Monticello is almost exactly 100 feet deep, and from one-fourth to one-half mile wide, and at Buffalo ten miles north of Monticello the channel is about 25 feet deep and is without floodplain or bluffs. In brief, the channel is just cut deep and wide enough barely to carry the flood waters. The trusses of the highway bridges crossing the river in Pulaski County can be seen miles away across the level prairie. The bridge floor at Winamac is level with the streets of the town. The river has a steep slope through this part of its course, the fall from Winamac to Monticello being not less than 100 feet in thirty miles.

The tributaries to the main stream in this region are examples of still younger drainage. In following the road from Monticello to Buffalo the way is over level country, except that where streams making their way

west to the river are crossed, the road descends ten or fifteen feet to the bridge crossing the stream, then rises by the same distance to the level plain again.


The Drainage of Pulaski and White Counties, Indiana.

Persons going to Headlee, Pulaski or Winamac (see map) often turn east a short distance north of Monticello and going about three miles they

turn north again, following the range line road. (Between R. 2 and R. 3 W.) This road is much more level. The streams crossed in small valleys on the west or river road have no valleys where crossed by the range line road. Formerly they existed as broad sloughs or strips of marsh land, and where crossed stretches of corduroy road were used to enable teams and vehicles to cross without miring. Scarcely the beginning of a channel could be discovered threading its way through the lowest part of the marsh or slough. The drainage was by over wash or sheet streams spreading out many rods in width and slowly creeping away to the river. Within the last mile or two of their course the channel became gradually deeper and wider and the stream sped freely down a steeper slope into the river. These sheet streams are good examples of the primary drainage or runoff. They were interrupted frequently by ponds and broader widths of marsh, keeping large areas so wet as to make cultivation impossible—the land furnishing a poor quality of pasturage.

Within the last few years man has done by machinery what nature has not done and could not do in thousands of years. Starting at the head of the sloughs fifteen to twenty miles from the river steam dredges have been used to dig channels for these over wash waters and practically every slough on both sides of the river in all this region has been furnished a channel ample for its drainage.

Pike Creek, Keen's Creek, the Carnahan Ditch, the Ackerman Ditch and Indian Creek on the east side of the river, and the Monon Creeks, Honey Creek and others on the west side, furnish examples of infant drainage aged by the aid of man in pushing forward the work the waters were so tardily doing.

# A Paired Entoplastron in Trionyx and its Significance.*

By H. H. Lane.

There is no order of reptiles more distinctly circumscribed than the Testudinata. Even the fossil remains cast little if any light upon their affinities. That they are a highly specialized group need not be argued. Any point, therefore, which gives an indication of what may be considered to have been a primitive condition in the order, is of extreme interest and value.

Moreover, there has been much discussion as to the relative rank of the various suborders and families comprised in this order. A group concerning which there is much diversity of opinion is that now generally regarded as constituting a suborder, the Trionychia. Some have seen in their so-called "soft-shelled" condition, evidence of extreme specialization, and have therefore assigned them to a very high position in the order. Thus, Gadow (Cam. Nat. Hist., vol. viii, p. 406) asserts that "It is not open to much doubt that the characteristic features of the Trionychoidea are not primitive but secondary. This is indicated by the whole structure and behavior of the carapace and plastron. The softening of the whole shell, the loss of the horny shields, the reduction of the claws, are the direct and almost unavoidable results of life in muddy waters." Other authorities take exactly the opposite view, and from the same facts reach the conclusion that "the Trionychidæ stand nearest to the general structural plan of the Reptilia" (Adolph Th. Stoffert, Structure and Development of the Shell of Emyda ceylonensis, Gray).

On account of this difference of opinion the writer has undertaken a study of the embryonic development of *Trionyx* with the view, *first*, of determining, if possible, the relative position of the Trionychia among the Testudinata, and, *second*, if it should prove to be a comparatively generalized type, to secure some hint as to the reptilian form from which the chelonian ancestry may have been derived. I present in this paper only one phase of the evidence furnished by the plastron, relative to the first of these two problems, although my material sheds some light upon both.

* (Contribution No. 5, from the Department of Zoology and Embryology, State University of Oklahoma.)

No other terrestrial or freshwater tortoises possess so simple and perhaps so primitive a type of plastron as that found in the Trionychia. In the adult *Trionyx (Aspidonectes) spinifer*, the plastron (Fig. 1) is composed of nine elements, four paired and one unpaired, separated to a greater or less extent at first by three, and later sometimes by only two, large fontanelles. Different authors have proposed different theories relative to the homologies of these plastral bones, and along with these theories there has arisen a complex terminology. Each author has sought to give permanency to his own hypothesis by assigning to the plastral elements names indicative of his view. Thus the unpaired element is designated by G. St. Hilaire, Owen, Ruetimeyer, and others, who regard the plastron as the homologue of the amniote sternum, as the "ento-sternal"; Parker calls it the "inter-thoracic plate"; while Huxley gives it the noncommittal name of "ento-plastron," in which he is followed by most later writers. The four paired elements of the plastron have not fared any better. Thus, G. St. Hilaire, Owen and Ruetimeyer designate them as "episternal," "hyosternal," "hyposternal," and "xiphisternal," respectively; Parker, as usual, has his own set of terms, and calls them "praethoracic," "post-thoracic," "praeabdominal," and "abdominal" plates; while Huxley gives them the names of "epiplastron," "hyoplastron," "hypolastron," and "xiphiplastron." In the present state of our knowledge it is best, perhaps, to use Huxley's terms, since they commit one to no special theory regarding the homologies of the elements to which they apply.

Among the various attempts that have been made to homologize the plastral plates with certain skeletal elements of other amniotes, one of the earliest was that of Cuvier (Regne animal, Les Reptiles, p. 10), who identifies them with the sternum of the Lacertilia and higher vertebrates. G. St. Hilaire (Philosophie anatomique, vol. i, p. 106) makes a detailed comparison between the several parts of the plastron and the osseous pieces of the avian sternum. Carus (Von den Ur-Teilen des Knochen- und Schalengeruestes, 1828), and Peters (Observationes ad Anatomiam Cheloniorum, Berolini, 1838), maintain that it is only partially equivalent to the sternum. Owen (On the development and homologies of the carapace and plastron of the Chelonian Reptiles, Phil. Trans. London, 1849), advances the idea that the paired plates correspond to haemapophyses of the ribs. Rathke (Ueber die Entwickelung der Schildkröten, Braunschweig, 1848), holds the plastron to be wholly dermal in origin and hence a structure not to be homologized with the endoskeletal elements of other groups. Many

of the more recent authorities, beginning with W. K. Parker (Structure and development of the shoulder girdle and sternum in the vertebrata. London, 1868), and Huxley (The Elements of Comparative Anatomy, London, 1864), consider the epiplastra and the entoplastron to be the homologues of the clavicles and interclavicle respectively, of other reptiles.

In form the entoplastron is quite as variable among the Testudinata generally, as are the paired elements associated with it. It is perhaps most frequently T-shaped or roughly triangular, with the apex of the triangle directed caudad. In *Trionyx*, however, it has an entirely different configuration, being in the form of a wide V with the apex or point directed cephalad (Fig. 1).

The other elements of the plastron have outlines and relationships characteristic of the family and can be easily identified by reference to the figure (Fig. 1), wherein the epiplastra (epi) are shown immediately cephalad of the entoplastron (ento), while the hyoplastra (hyo), hypoplastra (hypo), and xiphiplastra (xiph), lie caudad to that element in the order given.

In a Trionyx embryo with a carapace length of 14 mm., the elements of the plastron are all definitely laid down (Fig. 2). The nuchal plate of the carapace is a well marked and clearly defined dermal bone having as yet no connection with a vertebra. The ribs are fully laid down in cartilage, but there are no traces of costal plates, and neurals, likewise, are not present. The plastral elements are not only all present but they are also *all paired*. They are not preformed in cartilage but consist entirely of ossifications within the dermis. In shape and size they are clearly defined. As shown in the figure (Fig. 2) they form a series of five pairs of more or less rod-like structures, which are not in contact with one another, as is the case in the adult (Fig. 1), but on the contrary they are separated by comparatively large spaces in which the tissue of the dermis is clearly mesenchymatous and shows no trace of ossification. The position of the five pairs in two longitudinal rows and their absolutely similar origin as entirely dermal ossifications make it certain that, whatever their homology to structures in other forms may be, they must all be interpreted as serial homologues of each other. While it is agreed that the hyoplastra, hypoplastra, and xiphiplastra are the homologues of the abdominal ribs found in the Crocodile and Rhynchocephalia, the epiplastra and entoplastron are pretty generally regarded as representing the clavicles and interclavicle of other reptiles.

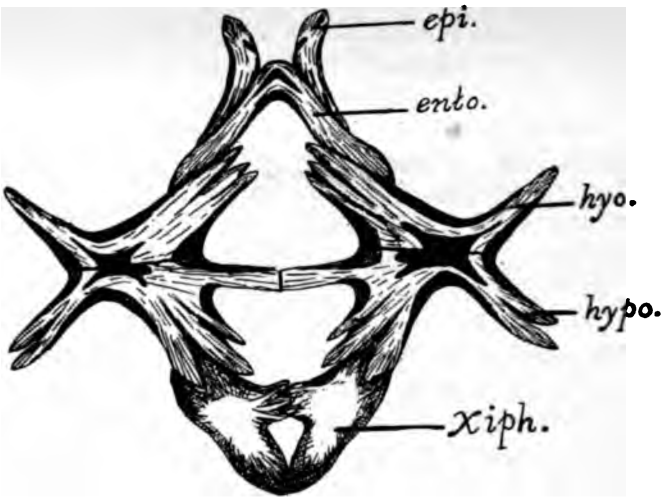


Fig. I

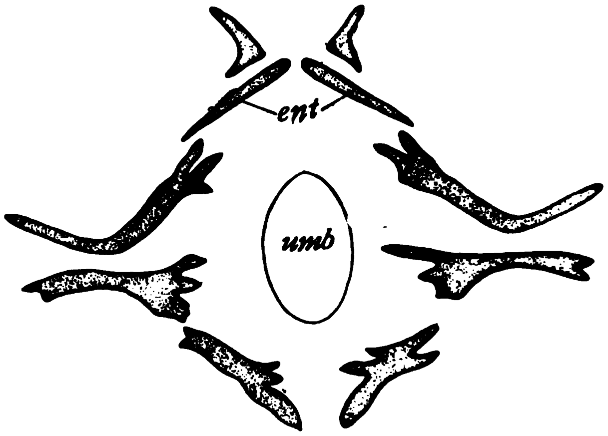


Fig. 2

EXPLANATION OF THE FIGURES.

Figure 1 shows the form and arrangement of the plastral elements (**reduced in size**) of an adult *Trionyx spinifer*, epi., *epiplastron;* ento., ***entoplastron;*** **hyo.**, *hyoplastron;* hypo., *hypoplastron;* xiph., *xiphiplastron.*

Figure 2 is a graphic reproduction, magnified ten times, of the plastral **elements in** embryo *Trionyx spinifer* with a carapace length of 14 mm. umb., ***umbilicus;*** ent., *paired entoplastra.*

Accepting merely for the moment the correctness of this homology, it is interesting to note how very rarely a paired interclavicle has been found in reptiles. So far as I have been able to discover Parker is the only one heretofore to report such an observation, and in his monograph on the structure and development of the shoulder girdle and sternum, cited above, describes the interclavicle of *Anguis* as developing from paired elements and says:

"Above the Ganoid Fishes, this is the only instance I can give at present of the primordial symmetry of the interclavicle; but a careful study of the development of this bone in embryo lizards would, very probably, show it to be not at all rare" (p. 99).

Examining the question of the homologies of the plastral elements a little more closely, however, one is led to doubt Huxley and Parker's identification of the epiplastra and entoplastron as clavicles and interclavicle respectively. In all other reptiles so far as known the clavicle is laid down, at least partially, in cartilage and in close connection with the other elements of the shoulder girdle. Even in the mammals, while its origin is still a matter for further investigation, it is definitely established that a portion at least of the clavicle is preformed in cartilage. In *Trionyx*, as in other of the Testudinata, the epiplastra, on the contrary, develop entirely without connection with the shoulder girdle, entirely outside the muscular layer of the body wall and within the much thickened dermis. They, in company with all the other plastral elements, are wholly without a cartilaginous preformation, and develop as direct ossifications in the dermal mesenchyme. Without further evidence it is very difficult to accept the view that the epiplastra are the testudinate homologues of the clavicles and the same arguments hold in regard to the identification of the entoplastron with the interclavicle. As is shown in this paper, the entoplastron in *Trionyx* is at first a pair of elements, so that there is nothing to prevent the interpretation of the entire series of plastral bones as the homologues of the so-called abdominal ribs so well known in Sphenodon and the Crocodilia.

Recurring to the question of the relative rank of the Trionychia among the Testudinata, the paired condition of the entoplastron, as it exists in this embryo (Fig. 2, ent) is especially important and instructive. As Rathke first pointed out, the entoplastron is wanting in *Sphargis*, perhaps on the whole the most specialized of all the Testudinata. It is reported by Stannius (Handbuch der Anatomie der Wirbeltiere, 1854) as absent

also in Staurotypus, while L. Agassiz (Contributions to the Nat. Hist. of the U. S. A., vol. I, p. 267) states that it disappears in old specimens of other Cinosternidæ. With these exceptions the entoplastron occurs as a single median bone in all known species of turtles and tortoises both living and fossil, save where in some of the latter the fragments are too meagre to permit its presence or absence being positively determined. It is therefore phylogenetically a very old element in the testudinate skeleton, and was probably, in some form or other, a direct inheritance from the more generalized reptilian stock from which this order arose.

It follows, therefore, that we have in the paired entoplastron of the embryo *Trionyx*, a very primitive character, so primitive, indeed, that it occurs nowhere in the adult of any known species of Testudinata either living or fossil. It is therefore an indication that *Trionyx* is to be regarded as more primitive than any other known genus of the order. Were this the only evidence of primitiveness known to occur in *Trionyx*, one would not, perhaps, be justified in making so broad an assertion. But a considerable amount of corroborative evidence is also at hand. Thus in *Trionyx*, the atlas is temnospondylous, i. e., its three constituent parts, the neural arch, the centrum, and the intercentrum, are not ankylosed but remain loosely connected, there is no odontoid process on the second vertebra, the first centrum being freely movable on the second; the pubic and ischiadic symphyses are broad and are connected with each other by a longitudinal cartilaginous band, which is replaced in other testudinates, except *Chelone*, by a broad completely ossified plate (Gadow). In the young of all tortoises, but in the adult only in the Chelonidæ and Trionychidæ, the plastral plates are separated by large fontanelles (Fig. 1, f). And finally, as reported by Wiedersheim (Vergl. Anat. der Wirbelthiere, 5. Auflage, 1902) teeth rudiments also occur in the embryo of *Trionyx* and *nowhere else among the Testudinata*. I have not been able so far to corroborate this observation, but it is certainly, if correct, a most important argument in favor of the view herein set forth.

This conclusion regarding the Trionychia is not invalidated by certain secondary specializations, such as the flatness of the body and the webbed feet, all clearly adaptations to an aquatic habitat. However, these adaptations do show that *Trionyx* is in no sense directly ancestral to the other Testudinata; the Trionychia are to be regarded as an early offshoot of the main stem, which has retained certain of its primitive characters.

State University of Oklahoma.
Norman, Oklahoma.

# Notes on Parasites Found in Frogs in the Vicinity of St. Paul, Minn.

By H. L. Osborn.

(Abstract.)

Our knowledge of the parasites of even the commonest animals is very incomplete. Examinations of all the organs and at all seasons of the year and extended over a period of several years have never been made except, possibly, for a few of the domesticated animals where the information possessed an evident and immediate utilitarian bearing. Such studies of a number of common and abundant animals are much to be desired. If a body of such information were available it would be of great service to students of the trematodes and very likely make it possible to complete many life histories, only fragments of which are known at the present time. The present paper is a first step in an attempt to do this with reference to the common frogs in the neighborhood of St. Paul. Twenty-one frogs were examined in June, seven in September and nine in November. These numbers are found to be too small for anything but a preliminary survey of the ground and larger numbers will be examined next year. The walls of the cœlom, particularly in the dorsal and anterior regions, are infected by nearly mature encysted individuals of *Clinostomum marginatum*, Rud. This form has been reported hitherto only from fish and fish-eating birds. The pericardial cavity, especially in frogs during June, was found to contain oval cysts, sometimes grouped in masses, each cyst containing a distome so immature that its generic affinities cannot be determined from the data furnished by a study of its structure. It may turn out to be a missing early stage of some trematode whose later stages are already known. The urinary bladder in a considerable fraction of the frogs examined harbors a species much like, if it is not identical with, the *Gorgodeda attenuata* which Stafford has described from a similar location in the frogs of Canada. A member of the Amphistomidæ occurs occasionally in the urinary bladder but is more characteristically a parasite of the rectum, where it is found at all seasons. In one instance *Cephalogonimus* was found in the rectum and small intestines. In a few cases a

cestode was found in the small intestine, also in the cœlomic cavity beside the small intestines and in cysts on the surface of the liver. The lungs contain *Distomum lanceolatum* in a large percentage of cases and a nematode also in many instances.

Hamline University,
St. Paul, Minn.

# The Mocking-bird at Moores Hill, Ind.

By A. J. Bigney.

The purpose of this brief article is to show how this bird acts on entering a new community, and to give evidence of its enlarging field of activity.

In Mr. Butler's catalogue of the Birds of Indiana[1] in 1897, they were reported in twelve counties in small numbers. In recent years they are migrating in large numbers into the counties of southern Indiana. In 1905, about April 1st, the first mocking-bird was seen in the outskirts of Moores Hill. It was rather shy, but made its whereabouts known by its incessant singing, not only in the daytime, but also during most of the night. Such singing had never been heard by our citizens. It continued this behavior for about ten days, then left the community. The next season a pair returned to the same place and the air was again filled with their music. Their usual imitation of the notes of other birds was a marked characteristic. This season they nested in the honeysuckle vine alongside a neighbor's house. They remained until late in the fall and then migrated southward. During this season one other pair was seen about two miles from town.

The following season several pairs were seen in and about town. The last two seasons the numbers have gradually increased, so that now they constitute one of our regular bird inhabitants.

The question naturally comes up, why have they begun their rapid advance into the north during the past few years? I can not answer this question. I have heard that a kind of ant is troubling them in their nesting and so they migrate to get rid of them. If any positive information can be given, I should be glad to know of it.

Moores Hill College,
Moores Hill, Ind.

[1] Amos W. Butler. The Birds of Indiana. Twenty-second Annual Report of the Department of Geology and Natural Resources of Indiana, 1897.

# Observations on Woodpeckers.

By John T. Campbell.

In May, 1883, I was surveying to build a levee along the east side of the Wabash River in Parke County, Indiana, from the mouth of Big Raccoon Creek southward to within a mile of the south boundary of the county—twelve miles long. Near the south end of this levee was a wide bottom, in which I had surveyed before it was cleared. Joseph J. Daniels, of Rockville, Indiana, bought this land, cut out the saw timber and deadened the remainder. In the spring of 1882, these deadened trees had decayed enough for the woodpeckers to bore holes for their nests. There were easily one thousand such trees on this seven hundred acres. Each tree had from three to twenty woodpecker holes. The marks of the great flood of 1883, in February, were very plain and could be recognized several years later. Of all those, probably ten thousand holes, not one was below the flood mark of the water of 1883. On the east side of the bottom the ground was very low, which made the flood marks about twenty feet above ground. The flood was twenty-eight feet above summer low water. Out west, near the river, the bottom was high, and the flood marks only about eight feet above the ground. Some of the holes were within two feet, but above the flood mark. The next year many holes were made below the flood mark, but whether they were kept above the top of the next and smaller flood, I did not think to notice. I ran the level over the land to grade it for assessment, and had a good opportunity to observe the holes. What is the explanation?

Lafayette, Ind.

# Observations on Cerebral Localization.

By James Rollin Slonaker.

Ever since Hitzig[1] in 1870 sent a voltaic current through the brain of a wounded soldier and noticed a certain movement of the eyes, numerous investigators have been busy furthering our knowledge of cerebral localization.

Fritsch and Hitzig followed this discovery with many experiments on the cerebral hemispheres of the dog and noticed that stimulation of certain areas produced definite muscular movements on the opposite side of the body.

These experiments started many other investigators, among whom may be mentioned Ferrier,[2] Munk,[3] Horsley and Schafer,[4] Heidenhain,[5] and Beevor and Horsley.[6] The results of these and many later investigations have formed the basis of an exact cortical localization in the brain of man.

Numerous surgical operations and pathological observations have added to our fund of knowledge, so that now the cortical areas governing certain movements in man are quite definitely known. However, each new case will further prove and assist in making the localized areas in man more definite. With this in view I present the following data which I have gathered from the subject:

Mr. Ralph R. Laxton of Atlanta, Ga., met with an accident which fractured the skull near the median line in the Rolandic region. A portion of the bone was removed to relieve the pressure on the brain. As life was despaired of no metal plate was introduced, but the scalp simply closed over. The wound healed and the subject finally recovered. The external condition of the wound after recovery is that there is a more or less circular depression about one and a half inches across, due to the

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[1] Hitzig, Reichert u. Du Bois-Reymond's Archiv., 1870.

[2] Ferrier, The Functions of the Brain, London, 1886.

[3] Munk, Die Functionen der Grosshirnrinde, Berlin, 1877-1880.

[4] Horsley and Schafer, On the Functions of the Marginal Convolution, Proceedings of the Royal Society, No. 231, March, 1884. Horsley, British Medical Journal, Vol. II, 1884.

[5] Heidenhain, Pflüger's Archiv f. Physiologie, 1881.

[6] Beevor and Horsley, A Record of the Results Obtained by Electrical Excitation of the so-called Motor Cortex and Internal Capsule in an Orang-Outang (Simia satyrus), Phil. Trans. Royal Soc., Vol. 181, B, 1890.

absence of bone. This depression lies as shown in Figures 1 and 2. These figures are shadowgraphs representing the side and back views respectively.

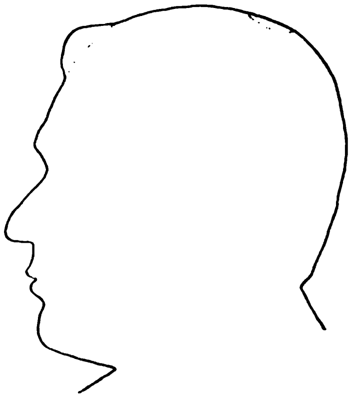

Fig. 1. Shadowgraph showing location of depression as seen from side.

Various muscular troubles arose, indicating a disturbance of the motor region of the brain. A line drawn outward, downward and forward at an angle of 71.5 degrees with the median line and starting from a point one-half inch, or about one centimeter, behind a point midway between the glabella and the inion, will approximately follow the central fissure[7], [8]. With such a line constructed one can quite accurately sketch in the outline of the brain and its principal fissures. Such a sketch is shown in Figure 3.

From this it is readily seen that the depression mostly affects the anterior central gyrus. Also by consulting Fig. 2 it is observed that the depression is situated almost wholly on the left side, passing over only about a quarter of an inch onto the right side.

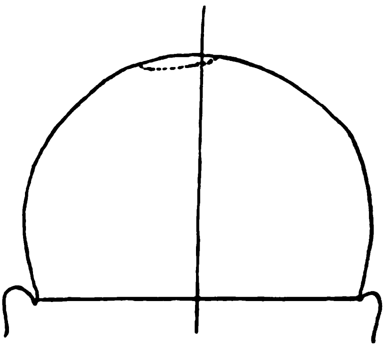

Fig. 2. Shadowgraph showing position of depression as seen from behind.

The schemes representing the localized areas in man are based on the results of observations on the monkey, on human pathological data and on experiments on man.

How Mr. Laxton's injury confirms our present knowledge of cerebral localization in man is shown in the following history of the case, a part of which I give in his own words:

"At the time of the injury, Nov. 25, 1892, I was 22½ years of age and weighed about 145 pounds. My height was about 5 feet 9 inches. At present I weigh 160 pounds and measure 5 feet 10 inches while standing on my left leg, and 5 feet 9 inches on my right.

[7] Deaver's Anatomy, Vol. II, p. 508.

[8] Reid, The Principal Fissures and Convolutions of the Cerebrum, Lancet, 1884.

"In perhaps sixty seconds from the time of the blow I was conscious again, but I do not remember any sensation in my right leg at the time, except that it was very cold. I did, however, observe the progress of paralysis in the right arm. This began in the fingers and extended gradually up the arm. For some time after I was operated upon I was unable to find the way to my mouth with a glass of water. This paralysis was, I think, due to extravasation of blood, which was gradually absorbed later, as I have for more than twelve years been doing a good deal of work with the pen and some with the telegraph key. I think I may safely say that I have entirely recovered the use of the arm. At times, however, I feel the characteristic dull sensation in the muscles of the right side of the body up to the shoulder, and even in the upper arm itself. Then, again, the sensation is hardly apparent above the waist line, all of which tends to show that the area of depression is not sharply defined."

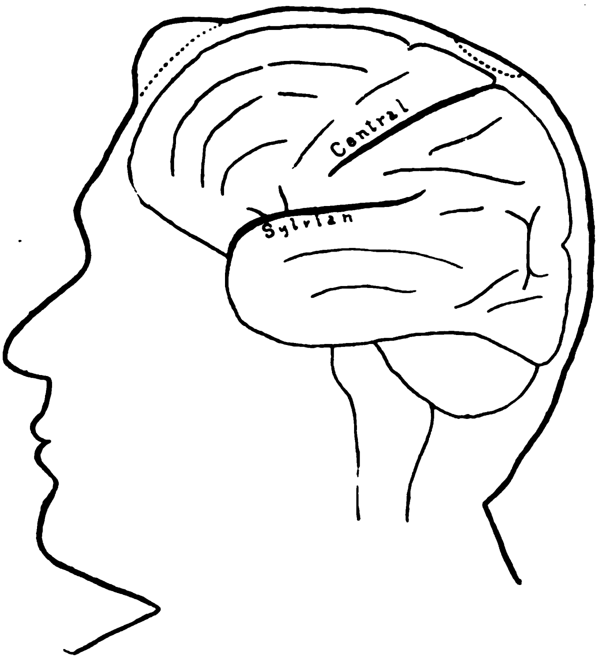


Fig. 3. Showing depression in relation to fissures of the brain.

The left arm was broken by the accident so he was unable to use it, but he states that it was not affected by the paralysis.

It would be interesting in this connection to know if the change in barometric pressure has any influence on the location of this dull sensation. Accurate observations in this respect are lacking. The only information Mr. Laxton can give on this point is as follows: "As regards baro-

metric effects, I have not been able to form any definite idea, though I have lived for ten months of the past year in southern Mississippi, where my office was just seven feet above the level of the Gulf of Mexico. I believe, however, that if the humidity of the atmosphere and the general condition of my system were exactly the same in both localities, I would find a difference between the sea level and a point three or four thousand feet above it. I have not had an opportunity to make observations in higher altitudes, but know that I am capable of more physical exertion in the mountains of western North Carolina than in the low country. I was on Lookout Mountain a few weeks ago, making the trip up the incline railway, but was not able to notice any change in feeling due to the rapid rise, of something like one thousand feet, from the city of Chattanooga to the top of the mountain. Just prior to a sudden change from dry to wet weather, I am apt to suffer from pains in the right leg, which I suppose are akin to rheumatism. As soon as precipitation begins the pains cease. This pain is most marked in the right hip joint."

In regard to stature, as has already been stated, he stands one inch higher on the left foot than on the right. The right leg also measures one inch less in circumference than the left, both in the thigh and the calf region. The muscles of the right leg, especially in the region of the calf, are less firm than those of the left. These conditions did not prevail before the accident. There is also a difference in the development of the two sides of the chest, which condition existed to a certain extent before the accident.

Concerning the resulting disturbances, Mr. Laxton says:

"There is a certain deficiency of sensation in the right leg and abnormal reflex action occurs. There is also an apparent deficiency of synovial fluid. There is almost an entire lack of control of the toes of the right foot, particularly the big toe (see Figs. 4 and 5). There is consequently a lack of balance in walking somewhat related to that observed in people who have lost one leg and use an artificial one. There are times when I feel for a few minutes as if the paralysis were entirely gone, but I have to be extremely careful not to feel too sure of myself and to follow the plan of not attempting a full length step with the right foot. The sensory paralysis extends very slightly to the bottom of the left foot." (Fig. 4.)

"I am just now experiencing considerable local irritation, the scalp even becoming, at times, sore on the outside. There are times when the

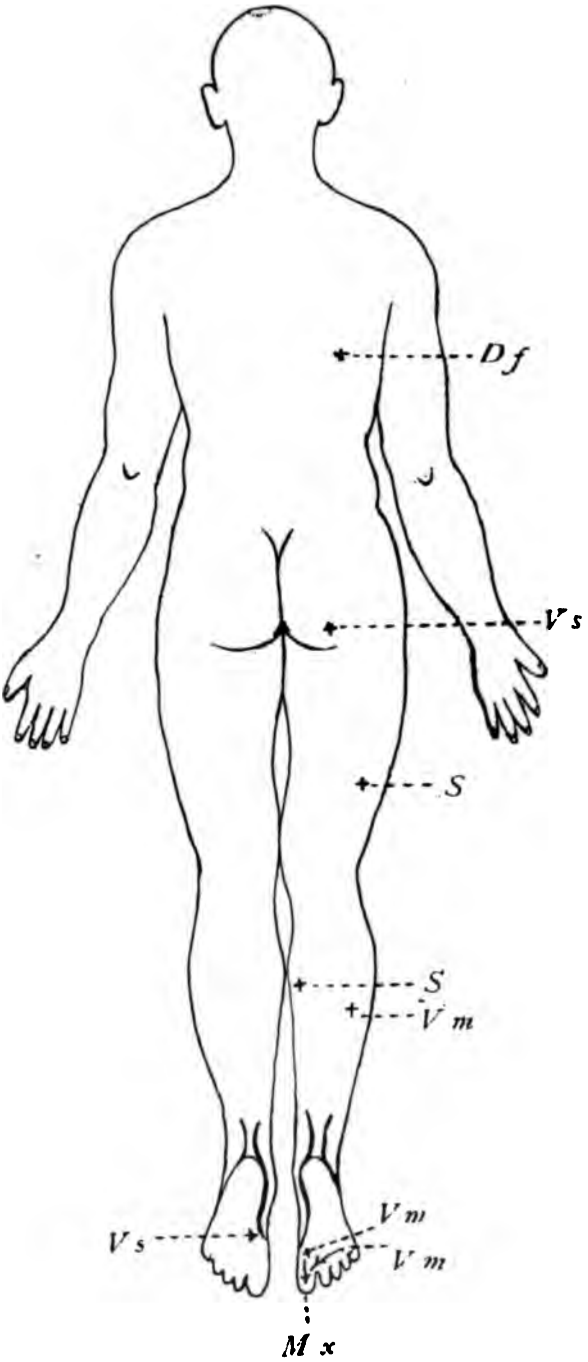


Fig. 4. Chart illustrating the positions of affected areas. Df, dull feeling; Vs very slight; S, slight; Vm, very marked; Mx, maximum.

under side of the scalp, the point of adhesion, has a feeling very similar to that of a vaccination scar just before the scab is ready to come off. Sometimes when I run my hand through my hair, I feel a slight tremor in the nerves of the calf of the right leg. The most sensitive part which gives rise to the tremor is the anterior edge of the depression."

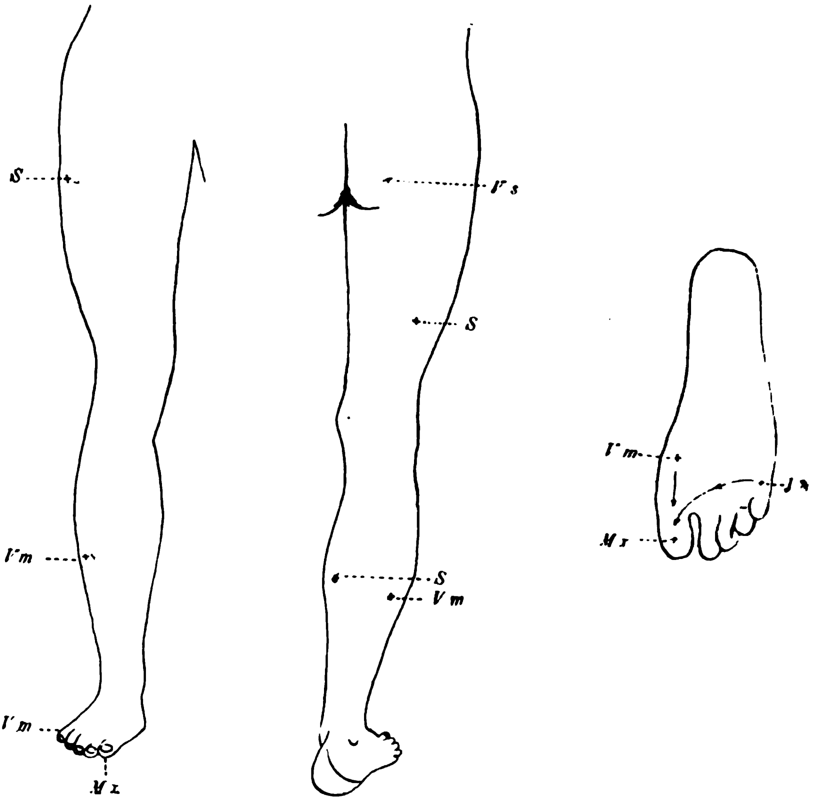


Fig. 5. Chart showing the position of affected areas in the right leg and foot Vs, very slight; S, slight; Vm, very marked; Mx, maximum. The arrows on the bottom of the foot indicate a continued but increasing disturbance.

In regard to the mental effect, Mr. Laxton says:

"There is no doubt that such an injury, so long as mechanical pressure continues, has at least a reflex bearing upon the mind itself, so that one suffering from it does not always feel like applying what he knows directly to the work in hand. If you will wear a brick fastened to your head con-

tinually for a term of years, or undertake a journey of indefinite length on foot through a tunnel not quite high enough to stand upright in, you will get an idea of the feeling."

In Figs. 4 and 5 I have indicated the location of the areas affected as described to me by Mr. Laxton. These areas range from a "dull sensation" to "very marked" and "maximum." It is interesting to note that the disturbance becomes more and more marked toward the feet. That while there is a great disturbance in all the toes of the right foot, this disturbance increases from the little toe and the center of the bottom of the foot to the hallux, where it is maximum.

One observes, also, that with the exception of a small area on the bottom of the left foot, which is very slightly affected, the disturbed areas lie wholly on the right side of the body. This we would naturally expect, as the greater part of the depression is on the left side of the median line of the skull. Since the depression extends slightly across to the right of the median line, we would expect some disturbance on the left side of the body. The slight disturbance on the bottom of the left foot would indicate that the portion of the brain close to the median line controls the center of the foot. We would expect a greater disturbance in the corresponding part of the right foot, because the corresponding area of the brain lies more nearly under the center of the depression.

We may, I think, reasonably infer that the region of greatest disturbance is controlled by that part of the brain lying under the center of the depression. Therefore the motor area controlling the movements of the great toe would lie about the center of the depression, and that of the small toes and the center of the bottom of the foot, in close proximity. As we have already concluded that the cortical area controlling the center of the bottom of the foot lies adjacent to the median longitudinal fissure, that for the small toes would be farther removed from this region than the center for the great toe. I think we may also conclude that the parts less and less affected are controlled by portions of the brain lying nearer and nearer the margin of the depression. The movement of the hair near the anterior margin producing a tremor in the calf of the right leg, would indicate that the motor center for this region is at this point.

Since all the muscles of a given region, i. e., thigh or calf of leg, are not equally affected, one may infer that different muscles of the same region may have somewhat widely separated centers of control in the cortex.

or that some of these centers may be more deeply seated than others, and for this reason less affected.

From the foregoing, I think the following conclusions can be drawn:

1. If we have made no mistake in locating the central fissure with reference to the area of depression, this area lies mainly over the anterior central gyrus of the left side and extends very slightly across the median longitudinal fissure to the corresponding gyrus of the right side.

2. The area controlling the center of the sole of each foot lies in the anterior central gyrus at the margin of the median longitudinal fissure.

3. The area controlling the hallux lies a little more lateral, perhaps one-half inch, from the margin of the median longitudinal fissure.

4. The area controlling the other toes is in close proximity to that of the great toe. It may be anterior, posterior or more lateral from that of the great toe. Since the region controlling the muscles of the calf lies anterior, it is very probable that it is more laterally situated. This accords with the results of Beever and Horsley.

5. The areas controlling the muscles of the calf on the outside and on the inside of the leg, the thigh, rump and scapular regions are located in the order named at greater and greater distances from the center of depression. I have no doubt that the scapular region (possibly some others also) is only indirectly affected.

6. Though the data are not quite sufficient to indicate accurately the position of the motor centers involved, it is very probable that they are arranged laterally along the anterior central gyrus from the median longitudinal fissure in the following order: a. Center of sole of foot. b. Center for great toe. c. Small toes. d. Calf muscles on lateral surface of leg. e. Calf muscles on mesial side of leg. f. Thigh muscles. g. Rump muscles. h. Scapular muscles. With the exception of the first-named area this arrangement agrees with the results of other investigations.

Leland Stanford Junior University,
California.

# The Development of Insect Galls as Illustrated by the Genus Amphibolips.

Mel T. Cook.

The study of the development of insect galls involves more complicating factors than most problems of evolution, since the host plant is forced to give both nourishment and protection to its enemy. The result of this enforced action is the formation of a structure which is normal for the parasite and pathological for the host. The histology of these gall structures presents some very interesting questions involving the point of stimulation, the character of the stimulation and the evolutionary lines along which the various species of galls have developed. For some time we have recognized that the point of stimulation is in the meristomatic tissues, and that in most cases the stimulation is not due to a glandular secretion from the parent insect.[1] However, there appears to be abundant evidence that in most cases the stimulation comes from the larva, but whether mechanical or chemical, or both, or the former in some species and the latter in others, is a practically untouched problem.

In 1902 the writer[2] advanced the opinion that "the morphological character of the gall depends upon the genus of the insect producing it, rather than upon the plant upon which it is produced, i. e., galls produced by insects of a particular genus show great similarity of structure, even though on plants widely separated; while galls on a particular genus of plants and produced by insects of different genera show great difference." Further studies along this line have convinced the writer of the correctness of this view, and have also led to efforts to work out a system of classification based on the histological character of the galls which would be correlated with the classification of the insects. However, the completion of such a series of studies is largely dependent upon a more satisfactory knowledge of the taxonomic relations.

While it is true that the histological characters of the galls depend upon the insects rather than upon the host plants, it is also true that we find certain characters common to all groups. The first step in the forma-

[1] Adler & Straton. Oak Galls and Gall Flies. 1894.

[2] Galls and Insects Producing Them. Ohio Naturalist, II:7, p. 270. 1902.

tion of a gall is (1) the excitation of growth and cell division, (2) the failure of the cells of the affected part to differentiate into the characteristic tissues of that part, and (3) the differentiation into characteristic tissues of the gall. We also recognize certain similar lines of development in what we now consider well-defined genera. The explanation of the similarities and differences in these lines of development will depend largely upon future work in both taxonomy and histology.

It is the purpose of this paper to call attention to certain points above referred to in connection with the genus *Amphibolips*. The taxonomy of the insects of this genera have been very thoroughly studied and carefully described and arranged by Mr. Wm. Beutenmuller.[3] The writer has also studied the histology of several of the galls.

The genus *Amphibolips* belongs to the family Cynipideæ, is quite distinct, and stands high in the line of development. As previously stated, the galls originate as a result of stimulation of meristomatic tissue, resulting in growth and cell division. This is followed by a differentiation of this mass of cells into the tissues characteristic of the galls. In the cynipidous galls we have the four distinct tissue zones which have been referred to by many writers, viz: (1) the epidermal zone, or outside layer of cells, (2) the parenchyma zone, which may be quite thick, either dense or loose, and in which may be found fibrous tissue radiating from the center of the gall, (3) the protective zone, composed of sclerenchyma tissue and varying in thickness in different species of galls, (4) the nutritive zone of parenchyma cells, rich in protoplasm and immediately surrounding the larval chamber. The galls belonging to this genus have the four well-defined zones, but with variation in the parenchyma and protective zones by which they may be subdivided into the following groups:

GROUP A.

*Amphibolips confluens*, Harris.
" *caroliniensis*, Bassett.
" *longicornis*, "
" *acuminata*, Ashmead.

[3] The Species of Amphibolips and their Galls. Bulletin of the American Museum of Natural History, Vol. XXVI, Art. VI, pp. 47-66. 1909.

GROUP B.

*Amphibolips inanis*, O. S.
" *ilicifoliæ*, Bassett.
" *Coelebs*, O. S.
" *citriformis*, Ashmead.
" *melanocera*, "
" *cinerea*, "
" *cooki*, Gillette.
" *tinctoria*, Ashmead.

GROUP C.

*Division a.*

*Amphibolips spinosa*, Ashmead.
" *globulus*, Beutenmüller.

*Division b.*

*Amphibolips nubilipennis*, Harris.
" *racemaria*, Ashmead.

*Division c.*

*Amphibolips prunus*, Walsh.
" *gainesi*, Bassett.
" *fuliginosa*, Ashmead.
" *palmeri*, Bassett.
" *trizonata*, Ashmead.

The writer has previously made studies of the histology of *A. confluens*, *A. inanis*, *A. ilicifoliæ*. *A. nubilipennis*, and *A. prunus*. Taking *A. confluens* as a type of the group A, we find the parenchyma zone very thick and composed of cells which when mature have the character of a mass of colored cotton, and among which may be found fibro-vascular bundles. The parenchyma cells, when examined under the microscope, are found to be unicellular, long and threadlike. The protective zone is comparatively thin. The nutritive zone is prominent only in the young galls. The writer has not had an opportunity to examine the other three species of this group, but from the taxonomic discussion, they appear to coincide very closely with *A. confluens*.

In group B the writer has studied *A. inanis*. *A. ilicifoliæ* and *A. coelebs*, which, judging from Beutenmuller's description, are quite typical of the group. In these galls the parenchyma zone is characterized by large intercellular spaces. A part of the parenchyma cells remain attached to

the epidermal zone, another part to the protective zone and some to the well-defined fibro-vascular bundles which radiate from the central body to the outer part of the gall. These fibro-vascular bundles are in general much better developed than in the galls of group A. The protective zone is subject to considerable variation in the different species; it is quite prominent in *A. inanis* and practically absent in *A. coelebs*. The nutritive zone, as in the first group, is prominent only when the gall is young.

In group C the writer has studied *A. nubilipennis* and *A. prunus*. This group may be readily divided into three sub-groups as indicated above. The species of sub-group (a) because of the inner radiating and spongy substance, appear to be intermediate between group B and the other species of group C. The species of sub-group (b) are more succulent than the species of sub-group (c).

My studies of *A. nubilipennis* demonstrate a thick parenchyma zone of large succulent cells and very small fibro-vascular bundles which were most numerous near the surface of the gall. The protective zone consisted of a few layers of thin-walled cells. The nutritive zone was prominent in the young galls and persisted quite late.

My studies of *A. prunus* demonstrated a very thick parenchyma zone, much firmer and drier than in *A. nubilipennis*, and in which were very few small, fibro-vascular bundles. The protective zone was entirely absent. The nutritive zone well developed in the young galls.

In general it will be noted that in this genus we have (1) the galls originating and developing in the normal manner which results in the formation of the four zones; (2) the variation in the parenchyma and protective zones, which enables the above division and sub-divisions; (3) that group A may be considered the most highly developed and sub-group c of group C the lowest. The significance of this line of development cannot be determined until we know more about other genera of gall-makers and their galls. However, a study of the known geographical distribution of the species of this genus is interesting in connection with this study. In group A, *Amphibolips confluens* is very widely distributed over Canada, the Eastern States south to Georgia, and west to Colorado, while the other three species have much more limited ranges, two and possibly all three within the range of the first. In group B we find that *A. inanis* ranges from Canada and the Eastern States west to Iowa and south to North Carolina; *A. cooki* has almost the same range; *A. ilicifoliae*, *A.*

*coelebs* and *A. tinctoria* are included within the above range; and *A. citriformis*, *A. melanocera* and *A. cinerea* are reported from Florida. In group C, we find *A. nubilipennis* very widely distributed from New York west to Illinois and south to Pennsylvania, *A. prunus* from New England west to Colorado and south to Georgia; *A. spinosa*, *A. racemaria* in Florida, *A. fuliginosa* in Florida and Georgia, *A. globulus* in New Jersey, *A. gainesi* in Texas, *A. palmeri* in Mexico, and *A. triazonata* in Arizona.

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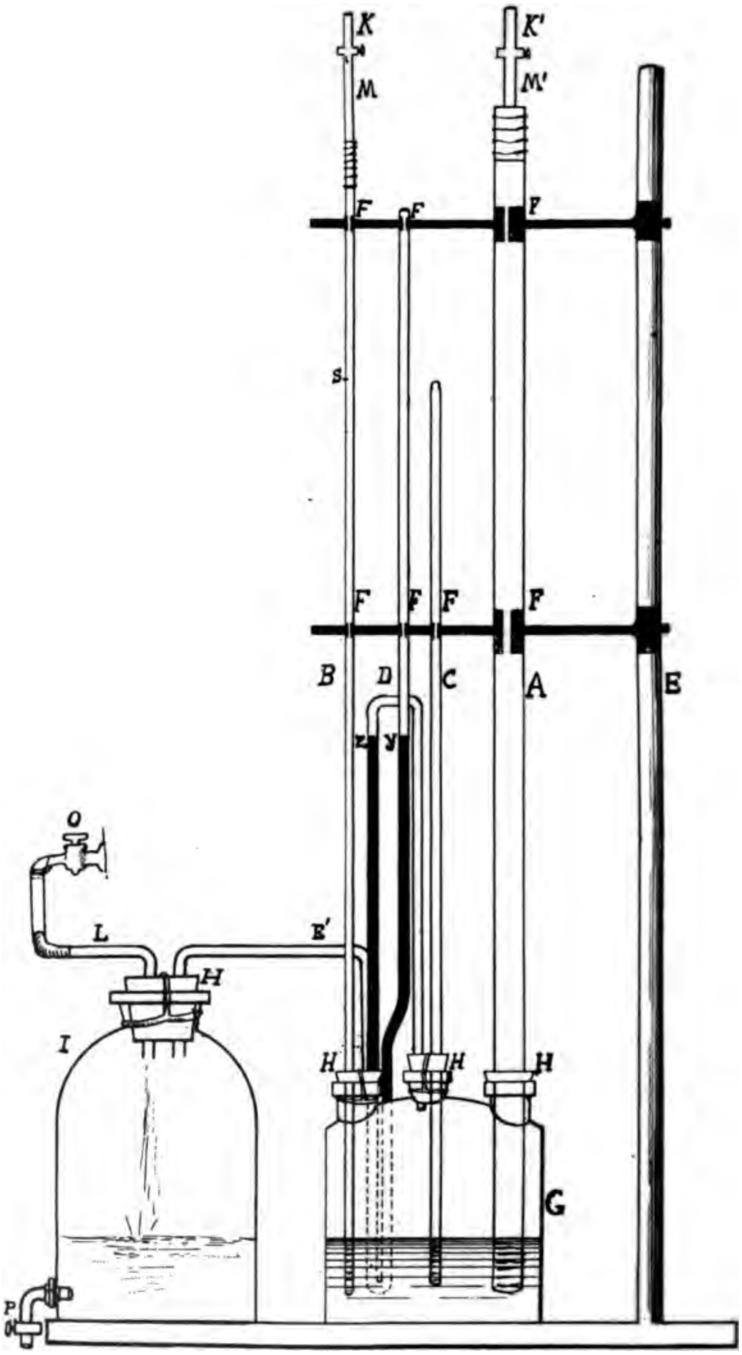
# Apparatus for Illustrating Boyle's Law.

By F. M. Andrews.

The apparatus shown in Figure 1 illustrates not only Boyle's or Mariotte's Law, but also a combination of attendant phenomena which I shall describe presently: Figure 1 is about one-fourth the true size of the apparatus. It consists of an ordinary iron ring-stand E, by means of which the various glass tubes A, B, C, and D, are held in the proper position by means of clamps at F. At the base is situated a Woulfe bottle G, with which A, B, C, D, and E′ communicate. The bottle G is about one-third filled with a concentrated aqueous solution of eosin. This solution is readily visible and on account of its intense red color is also seen at a considerable distance in the transparent glass tubes A, B, and C. Such an eosin solution has the additional advantage of being rather permanent in color, for in two years the solution I had used did not change perceptibly, and only a slight reddish brown precipitate was visible. It is also quite resistant in the presence of HCl, and even by the use of strong HCl a heavy precipitate results which is almost as red for a time as the original solution. The glass tubes A, B, and C extend below the surface of the eosin solution, while D merely projects through the rubber cork H. The connection of all the glass tubes A, B, C, D, E′, and L are made air-tight by means of the rubber corks H, and the latter are held firmly in place by copper wires to prevent their being blown out of the pressure generated in I and G. By means of the glass tube E′ the large glass bottle I is connected with G, and another glass tube connects I with the water-tap, air-pump or other contrivance for generating pressure. If the apparatus is connected as shown in the figure to water mains carrying a high pressure, and if then we open the valve O, the water will be forced into I. This will of course cause compression of the air in I, as well as pressure in proportion to the amount of water allowed to enter. Since G is connected with I by E′, the same pressure will be generated in G as in I. As A, B, and C project below the surface of the eosin solution, and if the valves K and K′ are closed and the water continues to enter I, in a few seconds the volume of air in the tube C, which is sealed at the top, will be compressed one-half its former volume by the eosin solution rising one-half the inside



Apparatus for Determining Boyle's Law.

length of the tube when the pressure in G equals one atmosphere. This illustrates Boyle's Law by showing that the volume of gas in C varied inversely as the pressure brought to bear upon it. The same principle would be shown in A and B under similar circumstances if K and K' of the tubes M M', which are fastened to A and B by means of rubber tubing held by copper fire and sealing-wax, remained closed.

Again, when the air in A, B, and C is compressed one-half its volume by a pressure of one atmosphere, this will be shown by the manometer which the tube D forms. This tube has each of its two arms filled to a height of forty centimeters with mercury. The total height of the two columns is therefore equivalent to more than an atmosphere. When the pressure in G is zero, then the two columns of mercury X and Y are equal in height. When, however, the pressure in G is equal to one atmosphere, then the column X will sink and column Y will rise till the difference of their heights is 76 cm. Since, in estimating accurately the height of a mercury column both pressure and temperature must be considered, this may be done by the usual formula.

When it is desired to again reduce the pressure in G to zero and allow the water in I to escape, this may be done by closing O, opening P, and either K or K', or both. Unless I is interposed between O and G, water could not for obvious reasons be used. Air could, of course, be forced directly into G.

The apparatus can also be used to show that the height to which a liquid will rise in a tube is independent of its diameter. If we open O then, as mentioned above, the pressure developed in I and G will cause the eosin solution to rise with ease in A and B if K and K' are left open. When the eosin solution has risen to S, or to any other height in B, whose internal diameter is three millimeters, then if we notice A, disregarding the small effect of capillarity in B, the column of liquid will stand at exactly the same height in A, whose internal diameter is one cm., as in B.

If, finally, both A and B are rapidly filled with the eosin solution by quickly and strongly generating pressure in G, then it will be seen by carefully timed observations that the liquid in A will rise to an equilibrium of the pressure in G somewhat more quickly than the same equilibrium will be attained by the liquid in B, due to the greater friction produced by the smaller tube B. For the same reason if the pressure is rapidly reduced to zero by opening P, the eosin solution in B will require a slightly longer time to fall from a point, as S, and reach the level of the liquid in G, than would be required by the same height of a column in A.

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# SOME MONSTROSITIES IN PLANTS.

By F. M. ANDREWS.

In the proceedings of the Indiana Academy of Science for 1905, pages 187 and 188, I have mentioned some interesting variations which I noticed in *Trillium*. Since that time I have been favored by the announcement of some additional monstrosities shown in Trillium by Prof. John M. Holzinger[1] of Winona, Minnesota, in a paper which he has been good enough eo send me.

It occasionally happens that interesting monstrosities or variations occur in other plants. Such variations, although very common, are nevertheless often of great importance.

One of the most common folear variations occurs in clover, and these I have found more or less abundantly, especially in *Trifolium pratense*. De Vries[2] states that he rarely observed clover individuals with more than one quaternate leaf. I have observed from time to time some specimens of clover which had one leaf of four leaflets, and in one instance found two specimens of clover, each of which had in addition to ten regular leaves of three leaflets, seven (7) other leaves, each one of which had four (4) leaflets. One of these quaternate leaves was beginning to form a leaf having five (5) leaflets by the splitting process. Again another plant of clover near this one having seven quaternate leaves, had in addition to the ternate leaves, one with five leaflets. Another specimen of clover had ten leaves of five leaflets each, in addition to several ternate ones. One of these leaves with five leaflets shows the origin of the supernumerary leaflets by the splitting process, as De Vries describes on page 342 of his "Species and Varieties. Their Origin by Mutation," 1905.

Another specimen of clover had in addition to the usual ternate ones, one leaf having six leaflets, and another plant of clover, one leaf having seven leaflets. These plants all grew close together in a yard and were the only ones thereabouts which showed, in the many other specimens of clover present, any of the above mentioned deviations.

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[1] John M. Holzinger, Plant World. 4: July, 1901.
[2] Species and Varieties. Their origin by mutation, 1905, p. 340.

I have also noted deviations in the Buckeye tree where six and sometimes nine leaves occurred instead of five. Some plants, as the common blackberry, have at times flattened stems, and some have two periods of blooming in the same year, as the Weigelas and other plants.

Apparent deviations or monstrosities may sometimes be due to an injury, and therefore in deciding such points care is necessary.

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# A List of Algæ.

(Chiefly from Monroe County, Indiana.)

By F. M. Andrews.

The list of Algæ given at the end of this paper includes about one hundred and seventy-five forms, most of which are from Monroe County, Indiana. Some few species of these Algæ are from the Eagle Lake and Turkey Lake in the northern part of Indiana, while a few others have been obtained from other sources. The collection of these forms has extended over a period of several years, for a continuous effort to obtain the forms here mentioned was not made except in the case of the Algæ found in the water works of this city in 1896. At this time some of the forms of Algæ then to be found in the city water works of Bloomington were collected by Dr. George J. Peirce, now of the Leland Stanford Junior University, Mr. A. C. Life, and myself. A title of the work done by us conjointly appeared in the proceedings of the Indiana Academy of Science for 1896, on page 208, entitled: "A Microscopic Examination of Certain Drinking Waters."

In this work not only the forms at the surface and edges of the reservoir were obtained, but also those to be found at different depths in the water. On account of the lack of more elaborate instruments and means for doing this, we hit upon a very simple but sufficiently effective plan. This was done by securing a bottle of the proper size and shape, fitted with a stopper, to a heavy cord. The stopper also was attached to a cord. After rowing out into the reservoir, the water of which varied from fifteen to thirty feet in depth, this weighted bottle was lowered to the desired depth by one string and the stopper partly removed by the other string. After the bottle had filled with water, as could be told by the rising of bubbles, the stopper was allowed to slide back in place, thus reclosing the bottle. To prevent the stopper from being pulled out of the bottle and thus rendering it impossible to replace it before raising the bottle from the water, a string of the proper length was tied around the neck of the bottle and to the stopper. To be sure that the glass stopper would settle back into the bottle after filling, I found a band of rubber fastened around the neck of the bottle and the stopper to be effective in accomplish-

ing this end. It is always best to close the vessel used in such experiments to prevent the entrance of Algæ not at the depth at which it is desired to take the samples or to keep some in the bottle from being lost in raising the bottle to the surface. In this way it is easily possible to obtain specimens that are floating from any part of the body of water. By this method, too, it was shown that numerous forms of Algæ were distributed all through this body of water. The living ones were found in greater abundance at or near the surface, as would be expected, but they were also found in the deeper water as well. In some places the number of forms was often very small, but in order to make a study of the greater number from such a locality the following method was used: A suitable quantity of water was obtained in the above described way from the desired location, and this allowed to filter through a small surface. A funnel, the lower end of whose tube was closed with closely woven cloth, served quite well, and in this way enough forms would be obtained for a convenient study. Such concentration of forms, we may term it, also brings about a great saving of time in looking for forms that would otherwise be found only after much searching, and at the same time was more representative for any given depth.

The effectiveness with which various of the Algæ forms could be removed by means of sand was attempted. This will vary with the kind of sand employed. The kind of sand here employed was very fine, white sand, especially employed for the microscopic examination of water. The following are some of the results:

Twenty-five ccm. of water from the bottom of the reservoir, in five cm. of this sand, required seven minutes to filter.

One thousand ccm. of water from the surface of the reservoir required forty-three minutes to filter, through a closely woven cloth tied over the end of a very small glass tube. A considerable depth of very fine, clear sand is necessary to entirely remove all of the smaller Algæ forms from the water, for I found after only twenty-five ccm. of the water from this reservoir had been filtered through five ccm. of fine sand, a considerable number of some forms came through. In one instance, in tap water, coming from this same source, some small forms came through four cm. of this fine, white sand, which to filter twenty ccm. it required one hour and twenty-five minutes.

In another case only eighty-five minutes was required to filter twenty-five ccm. of this water through four cm. of sand, due in this case to the less

quantity of sediment and forms than in the instance where one hour and twenty-five minutes was required for filtration. Some permanent slides were prepared in 1896 and part of these I still have, which show some of the various Algæ forms obtained by the method above referred to. These slides were prepared by making a mounting fluid of the following substances:

| | |
|---|---|
| Alcohol, 95% | 10 ccm. |
| Glycerin | 30 " |
| Distilled water | 30 " |
| Acetic acid, 5% | 30 " |

Specimens mounted in this mixture should be sealed with balsam. The slide should be thoroughly cleansed and dry before ringing the cover-glass with balsam. The only danger from the loss of specimens so mounted is from the liability of the balsam to crack and allow the liquid under the cover-glass to evaporate. For this reason they had better have the balsam covered with a layer of dammar-lac or shellac, and be noticed from time to time and not kept in too warm a place.

Dilute glycerin seems also to be a good medium for mounting Algæ. One specimen of Pandorina has been preserved and mounted in it fifteen years and is still apparently as green and as perfect as the day it was mounted. Camphor water[1] and glycerin also seem to give good results from the standpoint of preservation.

Other forms of the Algæ of this list not found in the water works reservoir have been observed at different times and recorded as found. It is not supposed that this list of Algæ here given is by any means complete, but gives an idea of a few out of an enormous number of forms that must be widely distributed. A good many of the forms here mentioned have been found by Mr. A. B. Williamson, one of the students in the Botany Department, and reported to me for the following list.

A list of the growing forms of plants in any locality is best made and more complete when extended over a series of years, so as to include those individuals which for various reasons or changes of conditions do not appear during one season.

[1] Stokes—Analytical Keys to the Genera and Species of the Fresh-water Algæ, p. 20.

## A LIST OF ALGÆ.

Glœocapsa polydermatica.
" aeruginosa.
" coracina.
" rupestris.
" sanguina.

Chrococcus turgidus.
" coherens.

Spirulina Jenneri.
" duplex.

Glœotrichia pisum.
" natans.

Calothrix gracilis.
Tolypothrix distorta.
" tenuis.

Rivularia Dura.
" echinulata.
Scytonema tolypothrichoides.
" myochrous.
" natans.

Sirosiphon pluvinatus.

Hapalosiphon tenuissimus.

Nostoc pruniforme.
" verrucosum.
" sphæricum.
" commune.

Anabæna inaequalis.

Nizschia sigmoidea.
" constricta.
" acicularis.

Cocconema lanceolatum.

Synedra Acus.
" pulchella.
Fragilaria capucina.
Achanthes Hungarica.

Cocconeis placentula.

Eunotia gracilis.
" pectinalis.

Amphora ovalis.

Epithemia turgida.
" gibba.

Gyrosigma attenuatum.

Spirogyra jugalis.
" nitida.
" crassa.
" decimina.
" setiformis.
" gracilis.
" fusco-atra.
" communis.
" quinina.
" longata.

Zygnema leiospermum.
" insigne.
" anomalum.

Zygogonium decussatum.

Mougeotia divarecata.

Mesocarpus nummuloides.
" recurvus.
" robustus.

Staurastrum arctiscon.
" muticum.
" dejectum.
" incisum.
" alternans.
" crytocerum.
" arachne.
" gracile.
" vestitum.
" hirsutum.
" spongiosum.
" luteolum.

Pediastrum Boryanum.
" pertusum.
" tetras.

Sorastrum spinulosum.

Cœlastrum microporum.
" cambricum.

Scenedesmus obtusus.
" dimorphus.
" caudatus.
" acutus.

Pandorina morum.

Endorina stagnalis.

Volvox globator.
Sphærella (Chlamydococcus) pluvialis.

Ulothrix subtilis.
" muralis.

Gonium pectorale.
Cladophora glomerata.
" fracta.
" crispata.

Œdogonium crassum.
" sexangulare.
" obtruncatum.
" fonticola.

Bulbochæte intermedia.

Colochæte irregularis.
" soluta.
" scutata.

Draparnaldia glomerata.

Stigeoclonium nanum.

Cylindrospermum macrospermum.
Cylindrocapsa geminella.
Merismopædia glauca.
" convoluta.

Oscillaria chalybea.
" cruenta.
" tenuis.
" subfusca.
" natans.
" antliaria.
" limosa.
" percursa.
" princeps.
" Froelichii.
" brövis.

Navicula viridis.
" sphærophora.
" serians.
" alpina.

Cymbella lanceolata.

Meridion circulare.

Diatoma elongatum.

Melosira arenaria.
" varians.

Gomphonema geminatum.
" constrictum.

Licmorphora flabellata.

Tabellaria fenestrata.
" flocculosa.

Pleurocarpus mirabilis.

Cosmarium obsoletum.
" sexangulare.
" globosum.
" orbiculatum.
" cucumis.
" suborbiculare.
" benustum.
" quasillus.

Closterium acerosum.
" cucumis.
" Ehrenbergii.
" acutum.
" attenuatum.
" Leibleinii.

Hyalotheca dissiliens.

Desmidium Swartzii.

Mesotænium Braunii.

Spirotænia condensata.

Docidium crenulatum.
" connatum.
" nodosum.

Tetmemorus Brebissonii.

Xanthidium armatum.

Arthrodesmus convergens.

Euastrum crassum.
" cuneatrum.
" didelta.
" ansatum.

Micrasterias radiosa.
" papillifera.
" truncata.

Chætophora pisiformis.
" elegans.
" tuberulosa.

Pleurococcus viridis.

Dactylococcus bicaudatus.
Botryococcus Braunii.

Hydrodictyon utriculatum.

Conferva floccosa.
" fugacissima.
" affinis.
" vulgaris.

Chlamydomonas pluviale.
" tingens.

Dictyosphærium reniforme.

Tetraspora cylindrica.
" lubrica.

Raphidium polymorphum.
" convolutum.

Vaucheria sessilis.
" gemmata.
" terrestris.
" sericea.
" Dillwynii.

Botridium granulatum.

Batrachospermum moniliforme.

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# Additions to Indiana State Flora, No. 4.

By Chas. C. Deam.

I offer the following as additions to the Indiana State flora. The determinations have been checked by recognized authorities, and specimens are deposited in my herbarium:

*Andropogon scoparius*, var. *littoralis* (Nash) Hitch.

Lake County, on sand dunes near Indiana Harbor.

*Panicum tennesseense* Ashe.

Madison County, on dry, wooded bank of White River, about two miles north of Anderson.

*Bromus altissimus* Pursh.

Allen County, on alluvial bank of the St. Mary's River, about one-quarter mile south of Ft. Wayne.

*Bromus incanus* (Shear) Hitchc.

Wells County, in Jackson Township.

*Carex canescens*, var. *disjuncta* Fernald.

Steuben County, on low border of Graveyard Lake.

*Carex laxiculmis* Schwein.

Johnson County, in dry woods about two miles southeast of Morgantown.

*Carex siccata* Dewey.

Steuben County, in dry soil in clearing one-quarter mile north of Clear Lake.

*Carex stellulata*, var. *angustata* Carey.

Steuben County, on low, sandy border on west side of Graveyard Lake.

*Celtis occidentalis*, var. *crassifolia* (Lam.) Gray.

Allen County, on bank of St. Mary's River one-half mile south of Ft. Wayne.

*Thalictrum revolutum* DC.

Fountain County, on wooded alluvial creek bank near Veedersburg.

*Trifolium dubium* Sibth.

Kosciusko County. Well established in yards of cottages on north bank of Lake Wawasee.

*Sanicula canadensis* L.

Allen, Blackford, Clark, Madison, Marion, Morgan, Wabash, and Wells counties.

*Sanicula gregaria* Bicknell.

Dekalb, Fountain, Madison and Noble counties.

*Cephalanthus occidentalis*, var. *pubescens* Raf.

Clark County, on State Reservation.

*Vernonia illinoensis* Gleason.

Steuben County, in prairie one-quarter mile east of Clear Lake. Clear Lake.

*Solidago juncea*, var. *scabrella* (T. & G.) Gray.

Wells County, in dry clay soil in clearing on east side of lakes in Jackson Township.

Indianapolis, Indiana.

# Right and Wrong Conceptions of Plant Rusts.

By J. C. Arthur.

The plant rusts have been known both popularly and scientifically from the earliest times. Their study took the usual course of development of all cryptogamic plants up to the time that DeBary demonstrated that pleomorphism existed in many species in a more striking manner than known in other fungi. He showed that most if not all members of the genus *Æcidium* as recognized at the time were only stages in the life cycle of species of *Puccinia* and *Uromyces*, and other investigators soon followed with similar demonstrations for such genera as *Roestelia*, *Peridermium*, and *Cæoma*. It was in 1866 that he announced, with experimental proof, that one stage of a rust, as the *Æcidium*, often grows on a host wholly different from that on which the final stage grows, such rusts being called heterœcious.

Heterœcism, which was thus established by DeBary and confirmed by his contemporaries, was not generally accepted by mycologists for a score or more of years. That the *Æcidium poculiforme* of the barberry leaf, with its conspicuous cups filled with chains of verrucose spores, could not give rise to other similar cups on the barberry, but only to the powdery and echinulate spores of the red rust on wheat stems, as unlike the former as a caterpillar is unlike the pupa into which it is transformed, was such a strikingly new idea in botany, that when once it did find general credence, and was extended to many other species by culture work, it assumed undue prominence. This result was accelerated by the rather recent discovery of races, or so-called physiological species. When the well known *Puccinia graminis*, which has great economic importance by producing a destructive disease of cereals and grasses, became also one of the best illustrations of the division of a species into physiological strains or races, more or less well established, in some cases amounting to possible species, it assumed in the minds of many mycologists a typical position in reference to other rusts. It became common to speak of rusts as agreeing with *Puccinia graminis* in their life cycles and spore structures, or in showing a certain amount of deviation from it. This attitude has caused considerable distortion in the conception usually held

of the rusts, even by the foremost students of the order. It affects systematic work adversely, keeps the terminology in an antiquated and ambiguous form, and makes it difficult to institute legitimate comparisons between different genera, species, or spore structures.

One of the wrong conceptions, wrong when viewed in the light of present knowledge, is to make the genus *Puccinia* include all species that possess a two-celled, pedicelled and free teliospore (excepting those with teliospore imbedded in gelatinous matrix, separated under *Gymnosporangium*), irrespective of the other morphological characters, or of the complexity of the life cycle, and furthermore, as part of the same conception, to make the genus *Uromyces* include all species that possess the same kind of teliospore, only one-celled instead of two-celled. The writer believes that the length and nature of the life cycle, which is a more unvarying character in the rusts than the one or two-celled teliospore (recall the *Uromyces-Puccinia* species on *Allium*, *Sida*, and some other hosts), should be accepted as a character for genera, as it is now quite generally accepted for species. Recognizing this as a valid generic character, and taken in connection with other characters, the genus *Puccinia* can be separated into four genera (i. e., *Dicæoma*, *Allodus*, *Bullaria*, *Dasyspora*), and the genus *Uromyces* also into four (i. e., *Nigredo*, *Uromycopsis*, *Klebahnia*, *Telospora*). If other characters, as well as the life cycle, mostly now generally ignored, are taken into account, *Puccinia Pruni-spinosæ* and its allies should form a genus (*Tranzschelia*) near to *Ravenelia*, on account of the adherent pedicels of the teliospores and peculiar structure of the urediniospores; *Uromyces rosicola*, on account of its evident spore structure, will go into a genus (*Amcris*) near to *Phragmidium*, but with a more limited life cycle; *Uromyces Terebinthi*, and its allies, on account of the remarkably distinctive characters of both urediniospores and teliospores, will form a genus somewhere between *Ravenelia* and *Tranzschelia*, while the similar *Uromyces effusus*, with a still more restricted life cycle, will go into another genus (*Discospora*). And in like manner quite a number of other species now commonly included under *Puccinia* and *Uromyces* could properly be separated and distributed to other genera, with much improvement in the nomenclature and great clarification of the systematic affinities. Other genera beside *Puccinia* and *Uromyces* could also be shown to be overburdened with species whose life cycle, or morphological structure, or both, entitle them to a different place in the systematic arrange-

ment, if the extent of the life cycle and characters other than those pertaining to the teliospore were called into account.

The third epoch in the study of plant rusts (the second one being ushered in by DeBary's demonstration of heterœcism and the first epoch preceding that time), may be considered to have started with the study of the nucleus and its behavior. This was begun by the work of Sappin-Trouffy and of Poirault and Raciborski some fifteen years ago, and ably continued by Blackman, Christman, Holden and Harper, Olive and others. The nuclear history in the rusts is still in a very incomplete state, and part of what has been gone over needs further substantiation. Enough has been demonstrated, however, to modify profoundly our ideas of the significance of the different spore forms, the relation of the spore structures, and the possibility of sexuality.

While it may be interesting to review the present knowledge of nuclear changes in the rusts and show the bearing on taxonomy, it will suffice for the present purpose to bring up briefly a few points. It has been rather clearly shown that the rusts possess well marked antithetic alternation of generations. The gametophytic generation has uninucleated mycelium, and gives rise to two kinds of spores, basidiospores and pycniospores, both uninucleated, and these are the only truly asexual spores formed in the life cycle. The sporophytic generation begins shortly after the pycnia mature, being inaugurated by a sexual fusion of cells. This act introduces the binucleated condition. In many species of rusts only one spore form (teliospore) is produced in the sporophytic generation. In other species there is an initial spore form (æciospore), and usually a repeating form, in addition to the teliospore. All spores of this generation are binucleated. In the gametophytic generation all species behave essentially the same. It is in what follows during the sporophytic generation that the great diversity of the rusts is shown.

If the first binucleated spores arising after sexual cell fusion are teliospores, no other spore forms in this generation are produced, and the life cycle is a brief one. But if the first binucleated spores are formed in what has been called an æcidium, cæoma, or primary uredo, they are essentially of the same physiological nature, whatever form they may take. Any such sorus may be called an æcium, and the spores æciospores, this being an extension in the previous application of the terms to cover the primary uredo. Possibly new terms would be less liable to introduce am-

biguity in subsequent discussions, but in this paper æcia will be understood to be the initial spore structures following the pycnia, when these structures are not telia. Such æcia are of varying complexity, the simplest being of the uredo-type with spores borne on pedicels and no peridium, intermediate forms being of the cæoma-type, with spores in chains and no peridium, and the most highly developed being of the æcidium-type with a well-formed peridium. There is a wide difference in complexity of structure between the lowest uredo-type of æcia (*e. g.*, those of the so-called *Chrysomyxa albida*) and the highest æcidium-type (*e. g.*, those of *Æcidium poculiforme* belonging to *Puccinia graminis*). But whatever the degree of complexity they are all strictly comparable in their relation to the life cycle of the different species to which they belong.

In most genera having species with initial æcia more rapid and extensive dissemination is brought about by means of repeating spores, often called summer spores. A few genera, like *Gymnosporangium* and *Calyptospora*, have no repeating spores in present known species. The repeating spore structures are either isomorphic with the æcia, and are known as secondary æcia and secondary uredinia, or they are heteromorphic, and are known simply as uredinia. In either case the repeating spores arise from an infection by initial æciospores, and are not immediately preceded by pycnia. Repeating spores are binucleated, but do not arise from fusing uninucleated hyphæ, as the initial æciospores do, for the mycelium on which they are seated is already binucleated, having been derived from a binucleated spore.

The accompanying chart enumerates the best understood genera of the rusts, arranged in such a way as to show the essential features in the life history of the species. It embraces about three-fourths of all genera of the Uredinales recognized at the present time. The chief value of the chart is to emphasize the need of taking into account the full life cycle in order to compare or to contrast genera. It will be seen that many genera, possibly a third of all known, have no æcia or repeating spores, but the formation of telia follows immediately upon the maturity of the pycnia. In the genera with æcia increasing complexity of development is shown by the presence of heteromorphic repeating spores, cupulate æcia with catenulate æciospores, and heterœcism while comparative simplicity of development is shown by isomorphic repeating spores, cæomate æcia with pedicelled æciospores, and autœcism.

## DIAGRAM

*Showing life history of 59 best known genera of rusts.*

- Pycnia
  - æcia
    - repeating spores heteromorphic
      - æcia cupulate—with catenulate spores
        - heterœcious: Coleosporium, Melampsoropsis, Pucciniastrum, Melampsoridium, Melampsorella, †Calyptospora, Cronartium, †Gymnosporangium
        - heter. and aut.: Nigredo, Dicæoma, Tranzschelia
      - æcia cæomate—with catenulate spores
        - autœcious: Eriosporangium, Neoravenelia, Phragmopyxis, Phragmidium
        - heter. and aut.: Melampsora
    - repeating spores isomorphic (autœcious)
      - æcia cupulate—with catenulate spores: Cystingophora, *Lysospora, Uromycopsis, Allodus
      - æcia cæomate
        - with catenulate spores: Earlea, Gymnoconia, Xenodochus, *Pucciniostele
        - with pedicellate spores: Ravenelia, Pileolaria, Uropyxis, Prospodium, Triphragmium, Trachyspora, Spirechina, Kuehneola, Argotelium, Bullaria, Klebahnia
  - telia
    - autœcious: Gallowaya, Necium, *Trichopsora, *Chrysomyxa, *Barclayella, Chaconia, Cionothrix, Alveolaria, Bæodromus, *Didymopsora, Dietelia, Endophyllum, Pucciniosira, Dendrœcia, Discospora, Macalpinia, Polythelis, Calliospora, Nephlyctis, Ameris, Nyssopsora, Polioma, Telospora, Dasyspora

*Not represented in North America.
†Repeating spores unknown.

It is evidently a right conception, in view of the foregoing statement, to regard *Puccinia graminis* (a better name is *Dicæoma poculiforme*) as a representative of the highest development of rusts. But to regard it as typical of all rusts, or even of all rusts having æcia, is clearly asking too much of an illustration, and likely to involve grave misconceptions of structure and relative values. If the most essential features of the rusts were to be illustrated by the smallest permissible number of examples of common and well known species, I should select *Polythelis Thalictri* (*Puccinia Thalictri*) for the forms without æcia, *Kuehneola albida* (often called *Chrysomyxa albida*) for the forms with æcia and isomorphic repeating spores, and *Dicæoma poculiforme* (*Puccinia graminis*) for the highly developed forms with æcia and heteromorphic repeating spores.

A wrong conception, which is doing much harm to the taxonomic study of the rusts, is the view that æciospores and urediniospores are of the nature of conidia, that is, asexual spores, comparable to the conidia so abundantly produced by many ascomycetous fungi. Cytological studies show, however, that in the rusts the only truly asexual spores, other than the basidiospores, are the pycniospores, and to these only can the term conidia be applied with approximate accuracy. The sexual process begins by the fusion of uninucleated hyphal cells, which immediately, or almost immediately, develop some kind of binucleated spore-structure. If only one kind of binucleated spore is produced by the species, it is properly called a teliospore. Such a teliospore has two nuclei in each cell, derived by a short succession of divisions from the two nuclei of the fusing cells. These two spore nuclei fuse into one nucleus prior to germination of the teliospore, thus completing the sexual process. If more than one kind of binucleated spore is produced, the initial kind may be called an æciospore, whatever the morphological structure in which it is formed. It has arisen as the consequence of sexual cell fusion, just as in the preceding case, and has the physiological character of greatly stimulated growth associated with sexuality. This initial æciospore gives rise to a binucleated mycelium, which in turn generally produces binucleated repeating spores of the same or of a different form, and so on, until finally a teliospore is produced in which nuclear fusion takes place, as in the first instance mentioned. The sexual process in this class of rusts extends from the cell fusion at the base of the æcia through all the succession of hyphal cells and repeating spores to the fusion of nuclei in the mature teliospore.

All rusts at present known fall into one of these two classes: the sporophytic generation gives rise either to a single spore-form, or else to initial and final spore-forms, with usually intermediate repeating forms. Whether one or more than one spore-form arises between the cell fusion and final nuclear fusion, constituting the sexual period, all such spores, of whatever morphological structure, are of a sexual nature, the initial form (whether of the æcidium-type, cæoma-type, primary uredo-type, or when none of these is produced, the teleuto-type) being the one which most clearly shows the stimulus of fertilization.

The above facts, especially when taken in connection with the highly differentiated structures associated with the initial and repeating spores, often being quite equal or superior to those of the teliospores, show every reason that may be based upon morphology and development for considering the initial and repeating spores as practically of equal taxonomic rank with the teliospores. To illustrate, a genus founded upon a repeating stage, like the genus of imperfectly known fern rusts, *Milesia*, should be as valid as if founded on the telia. This genus has recently been rechristened *Milesina* on the ground that the original name, given in 1870, is invalid because it was only applied to the uredinia and not to the telia. Again, now illustrating with a specific name, the heterœcious rust which was first specifically called *poculiforme* was described in its æcial stage under *Æcidium*, and according to the preceding argument on the importance of the initial spores, this name having priority, although not at the time made to include the telia, should be used, whatever genus name be considered the best, as *e. g.*, *Dicæoma poculiforme* or *Puccinia poculiformis*, not *Puccinia graminis*.

From the foregoing it will be seen that for purposes of taxonomy names applied to the pycnia (spermogonia) may properly be ignored, on the ground that they apply to asexual or conidial structures, but that names applied to æcia and uredinia (*Æcidium*, *Cæoma*, *Peridermium*, *Uredo*, and other such forms) should have the same standing as names applied to telia (teleutospore stage).

I have tried to show that the main features in the life cycle of all rusts exhibit essential uniformity, there being two large groups, one with a single form of spore (teliospore) in the sporophytic generation, and the other with additional initial and (usually) repeating spores, and that the great diversity lies in the details of their structural development. It is

difficult to give a clear and concise account of the general features of the rusts on account of the inadequate and ambiguous terminology at present in use. It appears to be unquestionably established that the spore structures of the rusts are not to be homologized with those of the Ascomycetes, and that taxonomic practice in the rusts should not be influenced by what is correct or expedient in the Ascomycetes or other fungi with strongly marked conidial and sexual forms, but be based upon the unique characters of their own development.

Right conceptions of the rusts, according to the writer's position, are those based upon the full life histories of the species, taking into account all the present known facts, and wrong conceptions are based upon partial life histories, and on ideas derived from other fungi and formerly supposed to apply to the rusts but now known to be inapplicable and misleading.

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# The Effect of Preservatives on the Development of Penicillium.

By Katherine Golden Bitting.

In examining ketchup for the organisms present, it was noted that the hyphae of moulds in preserved ketchup were swollen and distorted. In many of the brands of ketchup, the mould present was the common blue mould, *Penicillium*. As this mould is apparently omnivorous in habit, thriving and fruiting on many media, has been used in many physiological investigations to determine the nutritive value of many compounds, grows normally in liquid media, and fruits normally in a saturated atmosphere, is regular in its germinative power, and, so far as known, constant in form, it was selected to determine the effect of sodium benzoate, used in varying quantities, on its structure and development. The media used in the experiments were tomato bouillon, tomato gelatin, and tomato pulp, and were selected because the tomato juice and pulp are present in ketchup, and also because they do not alter the toxic properties of the agents used toward the fungus. Afterwards the condiments used in ketchup were tested and also the ordinary food preservatives, though not so extensively as the sodium benzoate. In these latter experiments tomato bouillon was the only medium used.

The bouillon was made by adding to a can of tomatoes an equal volume of water, boiling for about half an hour, and then filtering. The filtrate is clear, and a good medium for growth. It has an acidity of approximately .2% calculated as citric acid. For the tomato gelatin, 10% of gelatin was added to the tomato bouillon, cleared with egg, and filtered. The tomato pulp was obtained from a factory, and was made from whole tomatoes. To these media the sodium benzoate was added in the various amounts used in factory practice. Before sterilizing the media, calendered paper was tied closely over the cotton plug to prevent the distillation of the benzoate. After sterilization and cooling, the media were inoculated with spores from a vigorously growing culture of the mould. During development, the cultures were kept at room temperature, unless otherwise stated. The method of culture was by moist chambers and flasks for the bouillon and gelatin, and Petri dishes for the pulp. The moist

chambers had a few drops of the culture medium placed in the bottom. so as to keep the vapor tension unaltered.

The cultures were examined at regular intervals, as indicated in the tables, those in the flasks having specimens taken for examination with the miscroscope. The points noted were the swelling of the spores preceding germination, the length of hyphæ, and the earliest appearance of conidiophores, for the cultures in the moist chambers. For all other cultures a hand lens was used to determine the first appearance of germination. The appearance of the conidia was shown by the blue color, and the maturing by the change in color from the blue to green, and then to olive. The volume of mycelium and conidia was noted to determine the extent of development.

PENICILLIUM GROWN IN TOMATO BOUILLON 500 CC. 70° F.

| Per Cent Sod. Benz. | Time to Germ. Hours. | Development. |
|---|---|---|
| —— | 24 | Spores germinated.<br>48 hours—surface covered.<br>72 hours—spores developed, surface blue. Hyphæ uniform in outline, protoplasm homogeneous, many vacuoles.<br>120 hours—fully matured. |
| 1-12 | 48 | Thin ring at edge, small colonies submerged.<br>120 hours—surface covered, blue. Hyphæ, uneven outlines, protoplasm granular, walls broken easily<br>240 hours—fully matured. |
| 1-10 | 48 | Slightly less developed than in the preceding, otherwise alike.<br>240 hours—fully matured. |
| 1-5 | 120 | Thin interrupted ring at edge.<br>168 hours—spores swollen, irregular in outline, filled with coarsely granular protoplasm, walls broken by cover glass.<br>336 hours—surface dotted with colonies, showing blue spots.<br>348 hours—fully matured. |
| 1-2 | —— | —————— |

The effect of the sodium benzoate on the development is shown in a retarded and abnormal development, these being accentuated as the amount of the salt was increased, to a point where no development occurred.

PENICILLIUM GROWN IN 10% TOMATO GELATIN. 100 CC. 70° F.

| Per Cent Sod. Benz. | Time to Germ. Hours. | Development. |
|---|---|---|
| — | 24 | White colonies dotting surface.<br>96 hours—surface covered, green, mature. |
| 1-12 | 24 | Same as control. |
| 1-10 | 24 | Same as control. |
| 1-8 | 24 | Same as control. |
| 1-6 | 24 | Less developed than control.<br>96 hours—surface covered, nearly all green<br>432 hours—mycelium curled up round edge. |
| 1-4 | 48 | Small white colonies dotting surface.<br>96 hours—surface covered, nearly all green.<br>342 hours—mycelium curled from edges to center. |
| 1-2 | 72 | Small white colonies dotting surface.<br>96 hours—surface about two-thirds covered, center green.<br>342 hours—mycelium curled up so as to enclose the spores. |

In this experiment in which a solid medium was used, the effect of the sodium benzoate on the development of the mould was not marked, except in the cultures containing the larger amounts. In these there was a slight retardation, and also a curling up by the mycelium from the substratum.

PENICILLIUM GROWN IN TOMATO BOUILLON IN MOIST CHAMBERS, 70° F.

| Per Cent Sod. Benz. | Time to Germ. Hours. | Development. |
|---|---|---|
| — | 24 | Short tubes formed.<br>48 hours—well developed colonies formed. |
| 1-12 | 24 | Short tubes formed.<br>48 hours—colonies smaller than in the control. |
| 1-10 | 24 | Tubes just forming.<br>48 hours—less development than in the 1-12th solution. |
| 1-8 | 24 | Less than in the 1-10th solution.<br>48 hours—less than in the 1-10th solution. |
| 1-6 | 48 | Spores germinated, shorter tubes than in the 1-8th solution. |
| 1-2 | 96 | Spores germinated, short tubes. |

NOTE.—In 120 hours the control was exhausted, having empty hyphæ; the other cultures, with the exception of the ½% solution, have hyphæ with many vacuoles in the protoplasm, the conidiophores formed are apparently normal.

The effect of the antiseptic on the development of the mould grown in the moist chambers was not so pronounced as when a larger quantity of solution was used. Neither was the effect always uniform; sometimes the spores in the ¼% and the ½% solutions merely swelled, but no development of hyphæ occurred; in others short tubes developed from some of the spores, while still other spores showed no changes whatever.

To test the effect of the larger quantity of solution, inoculations were made into flasks containing 100 and 500 cc., respectively, of the solutions. The results indicated that the effect of the antiseptic on the mould development was greater when grown in the larger quantity of the solution.

PENICILLIUM GROWN IN TOMATO PULP, IN PETRI DISHES, 65° F.

| Per Cent Sod. Benz. | Time to Germ. Hours. | Development. |
|---|---|---|
| - - | 72 | White colonies dotting surface.<br>96 hours—spores formed.<br>192 hours—surface covered, green. |
| .1-12 | 144 | White colonies growing up on side.<br>192 hours—spores formed on one side, colonies starting in center. |
| 1-10 | 192 | Colonies started in center.<br>312 hours—spores formed. |
| 1-8 | 144 | White colonies growing up one side.<br>192 hours—spores formed. |
| 1-6 | — | ——— |
| 1-4 | — | ——— |
| 1-2 | — | ——— |

The pulp used in the experiments was of fine quality, and without any added ingredients such as are used in ketchup, and was used so as to determine the action of the sodium benzoate alone in the pulp. During the early stages of development, the mould grows down into the pulp, so that the whole surface of the hyphæ acts as an absorbent and would thus be affected to a greater extent than where only a part of the surface was in contact. This may serve to explain the more pronounced action of the sodium benzoate when in the pulp, and also the fact that after the mould has developed sufficiently to grow out of the pulp the development becomes more nearly normal.

The experiments were repeated many times and show slight variations, but the results as shown in the tables given are fairly representative.

## BENZOIC ACID IN CRANBERRIES.

The occurrence of benzoic acid in cranberries has been cited so often, and in a manner that is often misleading, figures obtained by Lafar[1] on the low-bush cranberry, *Vaccinium Vitis Idaea*, being given for the common cranberries, *Vaccinium macrocarpon* and *Vaccinium Oxycoccus*. *Vac. Vitis Idaea* is a common form in Europe, growing wild, and also in this country in Nova Scotia, and though it is imported into the United States, it is not the form which is used to any extent as compared with *Vac. macrocarpon*, the large cranberry and *Vac. Oxycoccus*, the small cranberry. The amount of benzoic acid in *V. Vitis-Idaea*, as quoted by Lafar, varies from .64–.86 grams per liter.

Testimony[2] given before the committee on interstate and foreign commerce of the House of Representatives on the pure food bills in February, 1906, gave the amount occurring in raw cranberries as ½%, and that half of this was volatilized in the cooking. It was not stated which of the two American species was used for the determination. These figures have not been verified, so far as known to the writer, though diligent search has been made in many chemical and food journals.

There is undoubtedly an antiseptic present in cranberries, a fact known to any one who has made either cranberry jelly or sauce, as these can be kept without spoiling for a long time, even when exposed to the germs in the air.

Experiments were made to determine the effect of growth in cranberry juice on the development of the organism used in the previous experiments.

The cranberries selected were the small oval ones, said to contain the largest amount of the antiseptic and were tested in three ways:

1. 200 grams were crushed in a mortar, then covered with 200 cc. water, and allowed to stand for 12 hours, after which the juice was filtered.

2. 200 grams placed in an open vessel in the sterilizer and steamed until the cranberries were soft, after which they were crushed in a mortar,

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[1] Lafar, F., Technical Mycology, Vol. I, p. 117, 1898.
[2] The Canner and Dried Fruit Packer, Vol. XXVI, No. 8.

had 200 cc. water added, then stood for 12 hours, after which the juice was filtered.

3. This was similar to 2, but the vessel was covered closely during the steaming.

For the experiments, 50 cc. of the filtrate from each set were placed in flasks. They were inoculated with the mould without any previous sterilization. The following table shows the time required for, and the effect on, development:

PENICILLIUM GROWN IN CRANBERRY JUICE.

| MEDIUM. | Days to Germinate. | Development. |
|---|---|---|
| Raw juice | 4 | Short tubes.<br>7 days—only small white colonies. |
| Juice cooked, open | 2 | Short tubes.<br>7 days—colony green. |
| Juice cooked, closed | 2 | Surface nearly covered, white.<br>7 days—surface green. |
| Raw juice+ 10cc. water | 3 | Small white colony.<br>7 days—surface green. |
| Juice cooked, open + 10cc. water | 2 | Surface nearly covered.<br>7 days—surface green. |
| Juice cooked, closed + 10cc. water | 2 | Surface nearly covered.<br>7 days—surface green. |

After two weeks' development, the color of the spores of Penicillium was a yellowish green, instead of the normal bluish green, and the mycelium was very scantily developed. The surface had a somewhat granular appearance, instead of the smooth, even appearance of a normal culture. The filaments, when seen with the microscope, were thin, shrunken, and clear, with distorted outlines. The cultures were kept for months, remaining scanty and granular looking, and a peculiar feature was that no development of bacteria occurred, even in the uninoculated ones, though no sterilization had been done, and the uninoculated were exposed to the

air at times. Sometimes the cultures become infected with yeast, which will develop in a normal manner, seemingly not affected as is the mould.

The antiseptic in the cranberries was weakened by the cooking, and it made little difference whether the vessel in which they were cooked was open or closed, development occurring in the same time in both. It is probable that the contained acid would evaporate to a greater extent if the cooking had been done on a stove, as they are cooked ordinarily, instead of in the enclosed sterilizer. It is also probable that some of the antiseptic property is due to the astringent present, which is said to be destroyed in the cooking[1], and which gives the raw cranberry its unpleasant taste. This is further borne out by the fact that the effect produced on the mould is different from that produced by the benzoate, used either as a salt or acid.

In nearly all the experiments with other media, in which sodium benzoate was used, in the lesser amounts, the organisms though delayed in germination, and at first forming an abnormal development, apparently became accustomed to their environment, and later developed fairly normally, which is different from the result in the cranberry juice, in the latter the restrictive effect persisted.

## CONDIMENTS.

The condiments used were those which are used in ketchup—salt, sugar, celery, cinnamon, cloves, garlic, ginger, mace, mustard, paprika, black, white, and red pepper, and vinegar. Along with these acetic acid and alcohol were also tested. With the exception of the cinnamon and cloves, the other spices showed slight antiseptic properties, so are not reported. They were tested in the form of infusions, made according to the method of the U. S. pharmacopoeia[2], also as acetic acid and oil extracts. The ordinary table salt and sugar were used. The quantities of the condiments used in the report were determined after a series of experiments had been made to locate their point of inhibition.

[1] Willis, C. R., Practical Flora, p. 174, 1894.
[2] U. S. Dispensatory, 19th ed., p. 651.

## EFFECT OF CONDIMENTS ON DEVELOPMENT OF PENICILLIUM.

Moist chamber cultures, capacity 1.23 cc.

| Solutions. | 20 Hours. | | 26 Hours. | 48 Hours. | | Description. |
|---|---|---|---|---|---|---|
| | Germination. | Hyphæ, Length in $\mu$. | Hyphæ, Length in $\mu$. | Germination. | Hyphæ, Length in $\mu$. | |
| Tomato bouillon | 100% | 56.0 | ........ | ........ | $\propto$ | |
| Tomato bouillon + salt, 5% | — | — | — | 100% | $\propto$ | |
| " " " 10% | — | — | — | — | — | |
| " " " 25% | — | — | — | — | — | |
| Tomato bouillon + sugar, 25% | 15% | 30.7 | ........ | 75% | ........ | Hyphæ distorted, appear empty. |
| " " " 50% | 5% | 24.0 | ........ | 75% | ........ | " " " " |
| " " " 75% | — | — | — | — | — | |
| Tomato bouillon + cinnamon, 5% | 100% | 136.0 | 369.1 | ........ | $\propto$ | Nearly normal, spores blue, vertical sterigmata. |
| " " " 10% | 30% | 40.0 | 230.7 | ........ | $\propto$ | Like the 5% but less development. |
| " " " 25% | 20% | 32.0 | 200.0 | ........ | $\propto$ | " 10% " " " |
| Tomato bouillon + cloves, 5% | 100% | 88.0 | 569.1 | ........ | $\propto$ | Hyphæ like the 5% cinnamon, heads close to germinated spore, few conidia formed. |
| " " " 10% | 25% | 48.0 | 369.1 | 50% | $\propto$ | Hyphæ well developed, no conidiophores. |
| " " " 25% | — | — | — | 10% | 722.8 | |
| Tomato bouillon + alcohol, 5% | — | — | — | 100% | Swollen | |
| " " " 10% | — | — | — | 10% | " | |
| " " " 15% | — | — | — | — | — | |
| " " " 20% | — | — | — | — | — | |

## EFFECT OF CONDIMENTS ON DEVELOPMENT OF PENICILLIUM.

Flask cultures, 50 cc. medium; 70° F.

| Solutions. | 48 Hours. | 72 Hours. | 96 Hours. | 120 Hours. |
|---|---|---|---|---|
| Tomato bouillon | Ring, heavy colonies, blue spots, many submerged colonies. | Ring 1/2" wide, older part blue | Ring, 3/4", green, surface dotted. | Ring thick, surface covered olive. |
| Tomato bouillon + salt, 5 % | Few small, submerged colonies. | Many small, submerged colonies. | Few surface colonies | Surface colonies curled, light green. |
| " " " 10 % | — | — | — | — |
| " " " 15 % | — | — | — | — |
| Tomato bouillon + sugar, 25 % | Thin ring at edge | Ring 1/4" wide, edge blue | Small surface colonies | Ring thick, surface nearly covered, green. |
| " " " 50 % | — | — | Ring barely perceptible | Thin ring at edge, green. |
| " " " 75 % | — | — | — | — |
| Tomato bouillon + cinnamon, 5 % | Large colonies at edge | Colonies enlarged, blue center, many sub. | Colonies increased in number, older ones green. | Surface nearly covered, thick, wrinkled, olive. |
| " " " 10 % | — | One small colony | Colony enlarged, center green | More colonies formed, oldest one olive. |
| " " " 25 % | — | — | — | — |
| Tomato bouillon + cloves, 5 % | Thin ring at edge | Ring 3/8", edge blue, many sub. col. | Ring 1/2", edge green | Ring thick, wrinkled, olive. Surface colonies. |
| " " " 10 % | — | Tiny colonies at edge | No change | Tiny colonies curled. |
| " " " 25 % | — | — | — | — |
| Tomato bouillon + alcohol, 5 % | Tiny colonies on surface | Colonies slightly enlarged, many sub. col. | Few colonies 3/8", curled | Colonies thick, wrinkled, blu . |
| " " " 10 % | — | — | — | — |
| " " " 15 % | — | — | — | — |
| " " " 20 % | — | — | — | — |
| Tomato bouillon + acetic acid, 1/2 % | — | — | Few surface colonies | Slight increase. |
| " " " " 1 % | — | — | — | — |
| " " " " 2 % | — | — | — | — |

The tables show the germinative power and also the gross effect in development. The moist chamber cultures gave closer results on the germination and the earlier effects on growth, but were not as satisfactory as the flask cultures in showing the general effect on development. In the flasks the amount of development, the method of formation, and the color in maturing could be seen to better advantage.

The 5% salt had a retarding effect, and also induced an abnormal development, the growth being confined to a small amount of curled surface mycelium not spreading normally over the surface, and some submerged colonies. The sugar caused a delayed, stunted development, sometimes the growth in the 50% consisting of a scanty, submerged mycelium. In lesser amounts than 25% a thin surface mycelium forms, with a thick layer of spores. The cinnamon and cloves in the 5% solutions were stimulating, while stronger solutions retarded the development, the cloves being stronger in action than the cinnamon. In the 5% solution of alcohol in the moist chambers the conidia became swollen as they do previous to germination, but no further development took place. In the flask cultures the action of the alcohol was weaker, the conidia germinating and forming small colonies, which was probably due to the evaporation of the alcohol, causing the solution to become weaker on standing. The ½% acetic acid retarded growth, and caused the mycelium to wrinkle. In all the flask cultures with the exception of the alcohol the effect of the condiment of corresponding per cent. was stronger than in the moist chambers.

## PRESERVATIVES.

The preservatives are those which have been used in foods, and used in approximately the same amounts. The results show that they have a retarding effect on the development of the mould, even when in small amounts, and that most of them become inhibitive when the amounts are increased, the increase not exceeding the amounts which have been used in foods.

# EFFECT OF PRESERVATIVES ON DEVELOPMENT OF PENICILLIUM.

Moist chamber cultures, 80° F.

| Solutions. | 21 Hours. | | 28 Hours. | 48 Hours. | Description. |
|---|---|---|---|---|---|
| | Germination. | Hyphæ, length in $\mu$. | Hyphæ, length in $\mu$. | Hyphæ, length in $\mu$. | |
| Tomato bouillon | 100% | 307.6 | 999.7 | ∞ | Conidiophores formed. |
| Tomato bouillon + sodium benzoate, 1-10% | 100% | 46.1 | 169.2 | ∞ | Conidiophores formed. |
| " " " " 1-5% | — | — | 30.8 | ∞ | Conidiophores starting. Only about 50% spores have developed. |
| " " " " 1-2% | — | — | — | — | |
| Tomato bouillon + benzoic acid, 1-10% | 25% | 30.8 | 46.1 | ∞ | Only about 35% spores have developed. |
| " " " " 1-5% | — | — | 15.4 | 769.0 | " " 50% " " |
| " " " " 1-2% | — | — | — | — | |
| Tomato bouillon + borax, 1-10% | 100% | 276.8 | 461.4 | ∞ | Conidiophores formed. |
| " " " 1-5% | 100% | 15.4 | 30.8 | ........ | No change after 28 hours. |
| " " " 1-2% | — | — | — | — | |
| Tomato bouillon + boric acid, 1-10% | 50% | 76.9 | 307.6 | 492.2 | |
| " " " " 1-5% | 50% | 15.4 | 30.8 | ........ | No change in hyphæ after 28 hours. 50% spores swollen. |
| " " " " 1-2% | — | — | — | — | About 10% of the spores swollen. |
| Tomato bouillon + sod. salicylate, 1-10% | 100% | 46.1 | 307.6 | ∞ | Conidiophores formed, but have few sterigmata. |
| " " " " 1-5% | 100% | 123.0 | 169.2 | ∞ | Thin mycelium, conidiophores formed close to germinated spore |
| " " " " 1-2% | 10% | 15.4 | 76.9 | ∞ | |
| Tomato bouillon + salicylic acid, 1-10% | 50% | 30.8 | 123.0 | ∞ | Like the 1-5% sod. salicylate. |
| " " " " 1-5% | — | — | — | — | |
| " " " " 1-2% | — | — | — | — | |

EFFECT OF PRESERVATIVES ON DEVELOPMENT OF PENICILLIUM—Continued.

| SOLUTIONS. | 21 Hours. | | 28 Hours. | 48 Hours. | Description. |
|---|---|---|---|---|---|
| | Germination. | Hyphæ, length in $\mu$. | Hyphæ, length in $\mu$. | Hyphæ, length in $\mu$. | |
| Tomato bouillon + sod. sulphite, 1-10% | 100% | 30.8 | 92.3 | 769.0 | Like the 1-5% sod. salicylate. |
| " " " " 1-5% | — | — | — | 153.8 | |
| " " " " 1-2% | — | — | — | — | |
| Tomato bouillon + saccharin 1-10% | 10% | 15.4 | 61.5 | ∝ | Conidiophores formed. |
| " " " 1-5% | — | — | 30.8 | ∝ | Conidiophores small, few. |
| " " " 1-2% | — | — | 15.4 | 507.5 | |
| Tomato bouillon + cop. sulphate, 1-10% | 100% | 30.8 | 169.2 | ∝ | |
| " " " " 1-5% | — | — | 15.4 | 276.8 | |
| " " " " 1-2% | — | — | — | — | |
| Tomato bouillon + sod. formate, 1-5% | 10% | 19.0 | ........... | ........... | |
| " " " " 1-2% | 2% | 11.4 | ........... | ........... | |
| Tomato bouillon + formic acid, 1-5% | 2% | 11.4 | ........... | ........... | |
| " " " " 1-2% | 50% | 11.4 | ........... | ........... | |

EFFECT OF PRESERVATIVES ON DEVELOPMENT OF PENICILLIUM.

Flask cultures, 50cc. medium; 80°.

| Solutions. | 24 Hours. | 48 Hours. | 72 Hours. | 18 Days. | * |
|---|---|---|---|---|---|
| Tomato bouillon | Tiny colonies at edge | Edge colonies 1/4" | Ring 1/2", center blue, many sub. col. | Surface covered, wrinkled, olive. Liquid nearly black. | 1 |
| Tomato bouillon + sod. benzoate, 1-10 % | — | Tiny colonies at edge, few submerged. | Slight increase | Surface covered, wrinkled, olive Liquid darkened. | 2 |
| " " " " 1-5 % | — | — | — | Surface nearly covered, green, mycelium still growing. | 8 |
| " " " " 1-2 % | — | — | — | — | |
| Tomato bouillon + benzoic acid, 1-10 % | — | — | — | Surface nearly covered, wrinkled, green, mycelium growing | 6 |
| " " " " 1-5 % | — | — | — | — | — |
| " " " " 1-2 % | — | — | — | — | — |
| Tomato bouillon + borax, 1-10 % | Tiny colonies at edge | Edge colonies 1/4", many submerged. | Ring 1/4" | Surface covered, wrinkled, drab, thin spore layer. Liq. dark. | 1 |
| " " " 1-5 % | — | — | Few tiny submerged colonies | Few surface col., curled, drab, thin spore layer, many sub | 3 |
| " " " 1-2 % | — | — | — | — | — |
| Tomato bouillon + boric acid, 1-10 % | Tiny colonies at edge | Edge colonies 1/4", many submerged. | Few surface colonies curled | Surface partly covered, curled, thin spore layer, many sub. | 1 |
| " " " " 1-5 % | — | — | Few submerged colonies | Same general appearance as 28, but less developed. | 3 |
| " " " " 1-2 % | — | — | — | Tiny submerged colonies. | 14 |
| Tomato bouillon + sod. salicylate, 1-10 % | — | — | Few colonies at edge | Surface nearly covered, wrinkled, olive, liquid darkened. | 3 |

*No. days to germinate.

EFFECT OF PRESERVATIVES ON DEVELOPMENT OF PENICILLIUM—Continued.

| SOLUTIONS. | 24 Hours. | 48 Hours. | 72 Hours. | 18 Days. | * |
|---|---|---|---|---|---|
| Tomato bouillon + sod. salicylate, 1-5 % | — | Few edge colonies, few submerged. | Larger than the 1-10 %.... | Same general appearance as the 1-10 % but less devel. Liquid slightly darkened. | 2<br>2 |
| " " " " 1-2 % | — | — | — | Colony on side, green, many sub. Liquid darkened slightly. | 12 |
| Tomato bouillon + salicylic acid, 1-10 %. | — | Few edge colonies, few submerged | Colonies curled.......... | Surface ¾ covered, dark olive. Liquid darkened. | 2 |
| " " " " 1-5 %. | — | — | — | Like the 1-10 %, but less developed, liquid lighter. | 4 |
| " " " " 1-2 %. | — | — | — | — | — |
| Tomato bouillon + sod. sulphite, 1-10 %. | — | — | — | Surface nearly covered, olive, many sub. col. Liq. darkened. | 4 |
| " " " " 1-5 %. | — | — | — | Ring at edge 1", blue to olive, many sub. col. Liq. darkened. | 10 |
| " " " " 1-2 %. | — | — | — | Few edge colonies, green, few submerged colonies. | 15 |
| Tomato bouillon + saccharin, 1-10 %.... | Tiny colonies at edge....... | Edge colonies ¼", many submerged. | Interrupted ring ½", center blue. | Surface nearly covered, wrinkled, olive. Liq. dark slightly. | 1 |
| " " " 1-5 %.... | — | Edge colonies ¼", many submerged. | Ring ¼", blue spots. | Slightly less development than the 1-10 %. | 2 |
| " " " 1-2 %.... | — | Tiny colonies at edge, many submerged. | Interrupted ring, surface colony curled. | Same as the 1-5 %. | 2 |
| Tomato bouillon + cop. sulphate, 1-10%. | — | Ring of colonies, many submerged | Surface nearly covered, older parts blue. | Surface nearly covered wrinkled, olive, many sub. | 2 |
| " " " " 1-5 %. | — | Ring of colonies, many submerged | Surface nearly covered, older parts blue. | Surface nearly covered, wrinkled, olive, many sub. | 2 |

| | | | | | |
|---|---|---|---|---|---|
| Tomato bouillon + sod. formate, 1-5 % .. | ——— | White ring, few submerged.. | Thick ring, blue at edge, many sub. | Surface covered, olive, many-submerged | 2 |
| " " " " 1-2 %.. | ——— | Thin interrupted ring, few submerged. | Many surface colonies...... | Surface covered, olive, many submerged. | 2 |
| Tomato bouillon + formic acid, 1-5 % ... | ——— | Thin ring, few submerged colonies. | Ring enlarged, blue at edge. | Surface covered, olive, many submerged. | 2 |
| " " " " 1-2 % ... | ——— | ——— | ——— | Surface nearly covered, green, many submerved. | 4 |

*No. days to germinote.

The results indicate the acid to be stronger in its effect than the corresponding salt, though *Penicillium* is a plant which grows luxuriantly on acid fruits. The sodium sulphite bleached the solutions, ½% being a pale straw color. The copper sulphate solutions were also changed in color, the ½% solution was a decided green.

In all cases microscopic examination was made of material from the flask cultures, and indicated more conclusively than the gross appearance the effect on the development. Submerged colonies have been used for the reports in the table, as they are more uniform. The surface colonies have the characteristics of the submerged in their earlier growth, but as development proceeds and the hyphæ grow away from the medium, the characteristics may change, sometimes more nearly approaching the normal, or they may develop characters more pronounced than the submerged. In a few instances, only submerged colonies, and in the raw cranberry and cinnamon solutions only surface colonies, developed. In making measurements the germinated spores were used, and only the average sizes; the extreme in size was avoided, as not giving a fair estimate of the effect of the preservative. Where only one measurement is given, it indicates that the spores were fairly uniform; where two measurements are given, the spores showed such strong variation that an average was taken of the smaller and also of the larger instead of taking the average of the two sets. The hyphæ were measured but varied so much that it was thought a better estimate could be obtained from the photographs.

MICROSCOPIC APPEARANCE OF PENICILLIUM GROWN IN PRESERVATIVE SOLUTIONS.

| PRESERVATIVE. | Size of Germinated Conidia in $\mu$. | Characteristics of Development. |
|---|---|---|
| Control | 8.5 | Hyphæ somewhat irregular in outline near germinated conidia, tapering tips, homogeneous protoplasm, many large round vacuoles. |
| Salt, 5% | 7.6 | Hyphæ short, distorted, homogeneous protoplasm, no vacuoles, blunt tips. |
| Sugar, 50% | 7.6 | Hyphæ shrunken, distorted, homogeneous protoplasm, vacuoles show as pink spots, giving a beaded appearance. |

MICROSCOPIC APPEARANCE OF PENICILLIUM—Continued.

| PRESERVATIVE. | Size of Germinated Conidia in $\mu$. | Characteristics of Development. |
|---|---|---|
| Cinnamon, 10% | 15.2 | Hyphæ swollen, blunt tips, protoplasm finely granular, without cohesion, walls break with weight of cover-glass. Few sepia in some, in others prominent. Few side branches. Hyphæ disorganized when placed in water. |
| Cloves, 10% | 13.3 | Hyphæ swollen, blunt tips thicker than older part, short thick side branches, finely granular protoplasm, not so badly disorganized as in cinnamon. |
| Cranberry, raw | 7.6 | Hyphæ shrunken, distorted, tendency to develop conidiophores close to germinated conidia. |
| Cranberry, cooked, open | 6.7 | Hyphæ thin, tapering, protoplasm finely granular. |
| Cranberry, cooked, covered | 7.6 | Hyphæ slender, tapering to threads, protoplasm reduced to lining of walls, coarse granules, many septa. |
| Alcohol, 5% | 15.2 | Hyphæ swollen, distorted, walls tough, protoplasm clear. |
| Acetic acid, 1-5% | 11.4 | Hyphæ enlarged, blunt tips, few septa, short side branches, proto plasm finely granular. |
| Sodium benz., 1-5% | 15.2<br>38.0 | Hyphæ and conidia swollen and distorted, no uniformity in formation of septa, some hyphæ, few, others many; protoplasm coarsely granular, filling tubes; walls break readily. |
| Benzoic acid, 1-10% | 15.2<br>49.4 | Hyphæ larger than in benzoate, more easily broken, distorted. Less swollen hyphæ have less distortion and less disorganization. |
| Borax, 1-5% | 9.5<br>15.2 | Hyphæ short, distorted or long and swollen, blunt ends, protoplasm clear, homogeneous or finely granular. |
| Boric acid, 1-5% | 15.2<br>19.0 | Hyphæ swollen, short thick side branches, blunt ends, protoplasm finely or coarsely granular. |
| Sodium salicylate, 1-5% | 9.5<br>15.2 | Hyphæ as wide as germinated conidia, few septa, granular protoplasm. |
| Salicylic acid, 1-5% | 15.2<br>30.4 | Hyphæ and conidia swollen, some of the conidia much elongated, hyphal ends blunt, few septa, protoplasm yellow, coarsely granular, protoplasm and walls disorganized. |
| Sodium sulphite, 1-5% | 11.4 | Hyphæ enlarged, few septa, protoplasm coarsely granular. |
| Saccharin, 1-5% | 13.3 | Hyphæ enlarged, some much swollen, slight distortion, clear, homogeneous protoplasm, thick, stunted conidiophores. |
| Copper sulphate, 1-5% | 11.4 | Hyphæ enlarged, slight distortion, protoplasm yellow, finely granular, dirty appearance. |

MICROSCOPIC APPEARANCE OF PENICILLIUM—Continued.

| PRESERVATIVE. | Size of Germinated Conidia in $\mu$. | Characteristics of Development. |
|---|---|---|
| Sodium formate, 1-5% | 13.3 | Hyphæ swollen, coarsely granular protoplasm, short side branches, blunt ends, disorganized, or normal size with fine granules and many vacuoles, some cells empty. |
| Sodium formate, 1-2% | 13.6 | Hyphæ swollen, coarsely granular, short side branches which do not develop, blunt ends, disorganized, break easily. |
| Formic acid, 1-5% | 14.0 | Hyphæ swollen coarsely granular, blunt ends, many broken, or normal size, finely granular, many vacuoles. |
| Formic acid, 1-2% | 11.4<br>41.8 | Hyphæ swollen, coarsely granular, yellow, distorted, badly disorganized, break easily. Nearly all germinated conidia broken. |

The sugar and salt caused the hyphæ to shrink and to assume distorted shapes when in sufficient amounts to cause a retardation. The cranberry juice, both raw and cooked, also caused shrinkage, and the raw juice a distortion. All of the others caused the conidia and hyphæ to swell and some of them also caused a distortion. The mould grown in the alcohol solution had tough walls in spite of the swelling, and a clear, sharp appearance. The borax and boric acid also produced a clear appearance. The sodium benzoate, benzoic acid, sodium salicylate, salicylic acid, sodium formate, formic acid, acetic acid, and cinnamon produced swelling, distortion, a disorganization of both the protoplasm and cell wall, and a yellowing of the protoplasm. The cell wall had no elasticity nor toughness, so that the placing of the cover-glass gently on a mount was sufficient to break the walls of the more distended hyphæ and to allow the protoplasm to flow out. The protoplasm appeared to be without coherence; when the wall gave way, it flowed in all directions, as if it were composed of loose particles having no cohesion. The sodium sulphite, saccharin, cloves, and copper sulphate growths had similar characteristics to those enumerated for the other preservatives, but not so strongly developed.

In summarizing the results, there seem to be two different actions induced by the action of the substances on the protoplasm, in one case a plasmolyzing effect causing a shrinkage and distortion, as in the salt and sugar, and in the other case a toxic effect producing a disorganization of both the protoplasm and wall, and a discoloration of the protoplasm, the substances showing varying degrees of toxic power.

## GERMINATION FROM PRESERVATIVE MATERIAL.

To determine if there were a permanent deleterious effect produced on the plant through the toxic effect of the chemicals, inoculations were made from two weeks' old cultures into tomato bouillon. The result is shown in the table:

GERMINATION OF PENICILLIUM GROWN IN PRESERVATIVE SOLUTIONS 14 DAYS.

| PRESERVATIVE. | Number Days to Germinate. | Stage of Development in 5 Days. |
|---|---|---|
| Control | 1 | Surface covered, green. |
| Sodium benz. 1-10% | 2 | Surface covered, green. |
| " " 1-5% | 2 | " " " |
| " " 1-2% | 4 | Thin ring, having blue dots. |
| Benzoic acid, 1-10% | 2 | Surface nearly covered, green. |
| " " 1-5% | 4 | Small surface colonies, blue. |
| " " 1-2% | - | ——— |
| Borax, 1-10% | 2 | Surface covered, green. |
| " 1-5% | 2 | One surface colony, green. |
| " 1-2% | - | ——— |
| Boric acid, 1-10% | 1 | Surface covered, green. |
| " " 1-5% | 2 | " nearly covered, green in center. |
| " " 1-2% | 5 | Few submerged colonies. |
| Sod. salicylate, 1-10% | 1 | Surface covered, green. |
| " " 1-5% | 2 | " " " |
| " " 1-2% | 1 | " " " |
| Salicylic acid, 1-10% | 1 | " " " |
| " " 1-5% | 1 | " " |
| " " 1-2% | - | ——— |
| Sod. sulphite, 1-10% | 3 | Colonies on surface, green. |
| " " 1-5% | 2 | Surface covered, " |
| " " 1-2% | - | ——— |
| Saccharin, 1-10% | 2 | Surface covered, green. |
| " 1-5% | 2 | " " " |
| " 1-2% | 1 | " " " |
| Copper sulphate, 1-10% | 3 | Colonies on surface, green. |
| " " 1-5% | 2 | Surface covered, " |
| " " 1-2% | 2 | " " " |

The germination and subsequent development indicate that the preservative affected the conidia deleteriously, as some were retarded, while the conidia from the solutions showing the strongest effects on the previous development, did not germinate, except from the ½% boric acid solution which formed a few submerged colonies, no surface development taking place. Lafar[1] states that the waterproof character of the conidial walls has a value in preventing the entrance of poisons to the protoplasm, but in the cases noted it is either dissolved by the chemicals or powerless to prevent their passage, for the results indicate that they exercised a decided toxic effect on the protoplasm.

## SUMMARY.

Salt and sugar injure the plant by preventing normal action of the protoplasm through plasmolysis.

Alcohol hardens the protoplasm and walls and prevents development.

Cranberry juice, both raw and cooked, retards development and causes shrinkage, though not having the appearance of the shrinkage due to plasmolysis.

All of the other chemicals tested acted as poisons on the protoplasm, retarding development and causing abnormal swelling and disorganization of varying degrees of intensity on both the protoplasm and cell membrane.

Lafayette, Ind.

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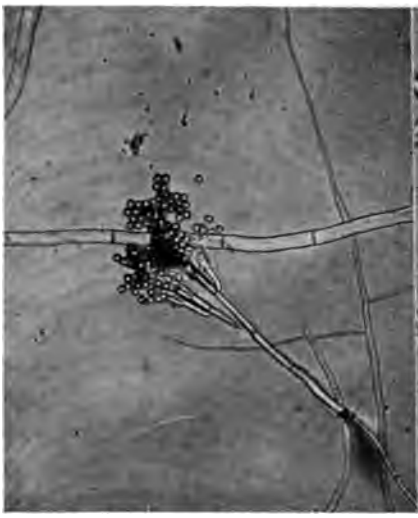
## EXPLANATION OF PHOTOGRAPHS.

The photographs have the same magnification, ×395, so that comparisons may be made as to the effect of the preservatives. The specimens were submerged colonies in all cases except the raw cranberry and cinnamon, and no submerged colonies developed in these solutions. The endeavor was to have all of the same age, but this was impossible, as some developed much more rapidly than others, and in those which were slow in developing it was impossible to determine the changes which the conidia may have been undergoing before the development had attained the colony stage. The submerged colonies were used as soon as they made their appearance. In some of the specimens that show little or no swelling the disorganization can be seen in the collapsed ends of the hyphæ and the floating fragments of protoplasm.

[1] Lafar, F., Technical Mycology, Vol. II, Part 1, p. 40.



1. Control - conidiophore and hyphæ.

2. Mycelium, grown in tomato pulp.

3. Hyphæ from ketchup preserved with sodium benzoate. The label gave amount as 1-10%.

4. Mycelium from 5% salt solution.

5. Mycelium from 50% sugar solution.

6. Mycelium and conidiophores from 10% cinnamon solution.

7. Mycelium showing disorganized hyphæ from 10% clove solution.

8. Mycelium from 10% vinegar (50 grain.)

9. Mycelium from 1·5% acetic acid solution.

10. Conidia from 9.6% alcohol soluti

11. Mycelium and enlarged conidium from 4·5% sodium benzoate.

12. Mycelium swollen and disorgani from 1·5% benzoic acid solution.

13. Colony from raw cranberry solution.

14. Mycelium with disorganized hyphal ends from cooked (open) cranberry solution.

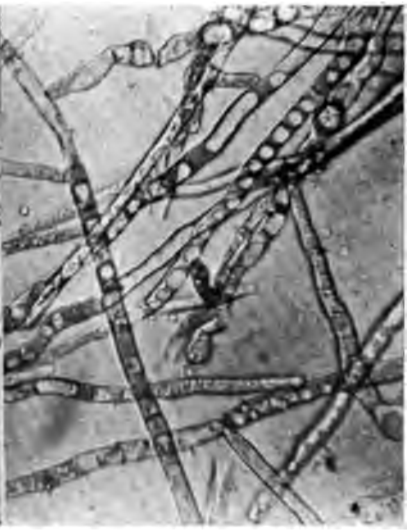
15. Mycelium with swollen conidia from cooked (closed) cranberry solution.

16. Mycelium from 1-5% borax solution.

17. Mycelium from 1·5% boric acid solution.

18. Mycelium from 1·5% sodium salicylate solution.

19. Germinated conidia and hyphæ from 1·5% salicylic acid solution.



20. Mycelium from 1·5% sodium sulphite solution.

21. Mycelium from 1-5% saccharin solution.

22. Mycelium from 1-5% copper sulphate solution.

23. Mycelium with disorganized hyphal ends from 1-5% sodium formate.

24. Mycelium with disorganized hyphæ from 1-5% formic acid.

# Further Notes on Timothy Rust.

By Frank D. Kern.

At the last meeting of the Academy, November 27, 1908, the writer presented a short paper on "The Rust of Timothy,"[1] in which the history of its occurrence in this country was discussed and its distribution at that time was given. The remark was made, although not incorporated in the paper, that this rust had not yet been reported from Indiana but that it was becoming more general in its distribution and might be expected here sooner or later. Since this prediction has come true within the year it is considered worthy of mention at this time. A collection consisting only of summer spores (urediniospores) was made in October, 1909, near Columbus, Indiana.[2] Last year the fungus was known in states both east and west of Indiana, so that while this report does not extend the range geographically, it is nevertheless of especial interest since it is the first definite information we have of its advent into the State. A second collection made in November at the same locality shows also a few winter spores (teliospores). It is of further interest to note that where the rust was found it was low ground with unusually rich soil. The place was originally a wet swamp but is now tile-drained. None was found on the high land adjoining. Low regions furnish more moisture in the atmosphere surrounding the plants, especially at nights, and this means better conditions for the germination of the spores.

In the paper read last year it was said that this rust was seemingly increasing in its distribution. The season of 1909 has proved the correctness of this prediction. A specimen was collected in September, 1909, in Maine by Dr. J. C. Arthur. This is the first collection that the writer has seen from the New England states. Last year Wisconsin was the most western state which had reported the rust. This year it has been found as far west as Minnesota, according to a report recently received from an official of the U. S. Department of Agriculture.

[1] Only an abstract of this paper appeared in the Proceedings of the Academy for 1908, p. 85, but it was published in full in Torreya, a Journal of the Torrey Botanical Club. Vol. 9, pp. 3-5, Jan., 1909.

[2] This collection was made by Mr. C. G. Hunter, on his farm near Columbus, and communicated by him to the writer.

The present known range is from Maine west to Minnesota, south to West Virginia and Indiana. Collections from the following states have been examined by the writer and are represented by specimens in the herbarium of Dr. J. C. Arthur at Purdue University, where the writer has carried on the major part of his studies. The collectors' names are included in parentheses.

Delaware (*Jackson*).
Indiana (*Hunter*).
Maine (*Arthur*).
Michigan (*Arthur, Kern*).
New York (*Webber, Reddick, Edgerton, Stone*).
Ontario (*Arthur, Dearness*).
Pennsylvania (*Sumstine*).
West Virginia (*Sheldon*).
Wisconsin (*Davis*).

During the year no additional facts have been brought out which throw any light on the specific standing of the timothy rust. The writer is still of the opinion that it is not entitled to specific rank and would include it under *Puccinia poculiformis* (Jacq.) Wettst. (*Puccinia graminis* Pers.) The statement made last year could, perhaps, be somewhat modified. Rather than calling it a race, physiological species or form species, it might be better to consider it a variety or subspecies since it does, as previously pointed out, possess some slight morphological differences from the typical form, particularly in the smaller æcial cups and the more delicate uredinial mycelium.

Purdue University,
Lafayette, Ind.

# The Woodlot for Central Indiana.

By E. C. Pegg and M. B. Thomas.

## INTRODUCTION.

The purpose of this paper is to show as accurately as possible with the information at hand the conditions of central Indiana woodlots and to make suggestions for their improvement and perpetuation.

## A SHORT HISTORY OF INDIANA'S FORESTS.

Early explorers of Indiana found a wilderness of giant trees. Upon the tops of hills and higher ground were such trees as beech, hickory, oak, hard maple, walnut, ash and tulip; in the richer lowlands were the elms, buckeye, basswood and soft maples; and tall sycamores and overhanging willows lined the banks of the streams. It was not uncommon to find trees nearly two hundred feet in height and twenty to twenty-five feet in circumference. Everywhere smaller trees, shrubs and herbaceous plants struggled for their requisite amounts of sunlight. A spongy mass of forest litter made a floor that held rainfall and fed the innumerable springs, which in their turn supplied the streams and rivers with a constant and uniform volume. Such was the unbroken forest.

*Clearing.*—It was soon discovered that Indiana's soil was well adapted to agriculture. The early settlers began the work of forest destruction by clearing their homesteads for agricultural purposes. Regular log-rollings were held at which tree after tree was cut down, piled in log heaps and burned. Such work at that time was justifiable because timber was very plentiful and because the ground thus cleared was necessary to furnish a living for the ever increasing population.

*Lumbering.*—For this reason much of the land was cleared. Official records, which begin in 1870, show an acreage of 7,189,334 acres in timbered lands. In 1880 only 4,335,000 acres were left. As Indiana became more thickly settled, better houses, cities, roads, railroads and factories were being built, each requiring a certain amount of timber for construction. And in additional ways the consumption steadily increased. The towns and cities afforded market places, the roads and railroads a means of transportation for lumber. Thus began the other chief influence in

forest destruction. By 1890 over 2,500,000 acres more were cleared, of which 75,000 acres became waste land. The timber supply of the East was falling, the demand increasing. Then Indiana ranked fifth with the states of the Union in the total output of lumber. In 1907 she ranked twenty-seventh.

At the present time there are probably less than a million acres of woodland in the State. This fact shows us the truth of the prophecy made twenty-five years ago that "At the present rate of consumption the forests of the State must soon cease to be commercially important." Very little now remains of the once seemingly inexhaustible supply of valuable timber, such as oak, walnut and yellow poplar.

*Formation and Evolution of the Woodlot.*—It is with this small remainder, especially that portion which lies in the central part of the State, that this paper deals. Formerly the farmer removed only the timber on the land he actually needed for agricultural pursuits. Gradually, as his needs increased, he extended the boundaries of his fields. The trees which he removed more than furnished him with firewood and other necessary timber. But when a market was opened up the owners began to cut the still vast forests for purely financial reasons. These became more and more exhausted until now very few acres of virgin timber, and comparatively few of any kind, remain. The farmer is at present apparently satitfied with his acreage of cultivated land, good timber is too scarce for extensive clearing or sale, and he is willing that a small portion of his farm should remain covered with a more or less depleted forest in order to provide wood for general purposes about the farm. These are the chief reasons for the presence of a woodlot today. Some timber was left because it was difficult to reach. Other tracts were left because of the pasturage they afforded in the grass which sprang up when the dense forest cover was partially removed. So, for one reason or another, or purely by accident, certainly not from choice, the woodlot of today occupies the position it does, oftentimes on the best land of the farm.

*Present Conditions.*—To get an idea of the present condition of these woodlots one need only travel a few miles in the country. In the distance he can see trees in a seemingly unbroken line. Closer examination, however, shows them to be in small, scattered patches ten to thirty acres in extent. After the best trees had been cut out and sold, the custom of cutting trees for special uses, such as handle stock and spoke material, led

to the removal of the next best. All the most valuable species, black walnut, yellow poplar, white ash and the best oaks, have been cut away, leaving only a few maples, beech, ironwood, buckeye and the like. Many of these are crooked, defective and otherwise undesirable. At no time has any care been exercised to protect the undergrowth of young seedlings. The floor also presents a very different appearance from what it once did. A dense bluegrass sod has taken the place of the undergrowth and rich forest litter destroyed by constant pasturage. A heavy growth of grass is in itself an enemy of trees, for it not only makes reproduction harder but also smothers the roots of those already growing and robs the soil of moisture so essential to good tree development.

Some may ask what it matters if the conditions are thus. Are not the farmers in better circumstances now than they were forty years ago, yes, even ten years ago? Financially they are, but with wise and proper management of their woodlots they could realize still larger profits from their farms.

## THE WOODLOT.

### USES.

There are many reasons why woodlots are valuable. They furnish timber for all farm needs, protect buildings and crops, shelter live stock and materially help in preventing erosion and in ornamenting the country.

*Firewood.*—Firewood comes first in the list of timber used for farm purposes. The early methods of using wood in a fireplace were wasteful. The introduction of stoves resulted in a great saving of fuel. But fuel production was not the only purpose served by the forest. Now lack of timber and the cost of getting crooked and knotty trees cut into firewood have compelled the use of a substitute. Most farmers would be glad to have again a plentiful supply of cheap fuel.

*Posts.*—The setting of 1,000,000,000 (estimated) fence posts per year shows us another very important use for timber. According to the last census 8,715,661 of these posts were produced from the regular logging camps of the country. The use of these posts as supports for woven wire fence is very economical when compared to the former practice of building rail fences, many of which were of black walnut, the most valuable timber Indiana ever produced. Their gradual displacement by wire or picket fences is a great step towards forest preservation.

*General Farm Uses.*—Then there are other innumerable general uses about the farm for poles, boards and lumber. After all these needs are satisfied there should remain some timber (logs and railroad ties) for market.

*Climatic Influences.*—The influence of woodlots on the climate makes their presence desirable. A great deal has been written about forests as a factor in rainfall, but it has never been satisfactorily proved that they increase the total amount. It is known, however, that about twenty-eight per cent. less of the annual rainfall is evaporated within the woods than outside of them, and that the mean annual temperature of forest soil is about twenty-one degrees lower than that of cultivated fields. In summer this cool soil tempers the air above, and by starting currents from the adjoining fields lowers their temperature. Besides, woodlots, if situated in favorable positions, check strong winds, in this way protecting farm buildings and preventing fruit trees and crops from being blown down.

*Shelter.*—A woodlot is invaluable for the shelter it affords to live stock in both summer and winter. Less food is required to maintain the body warmth of animals when they are well protected from the cold winter winds. Therefore the use of grain in fattening stock is much economized. The cool shade offered by a small portion fenced off from the best part of the woodlot prevents fattening animals from losing flesh during the hot weather.

*Aesthetic.*—But these uses are not all. Every one knows that a good strip of timber greatly increases the value of a farm, for by this means not only the beauty of individual farms but also that of the entire community is increased as much, if not more, than by more expensive improvements. For no other reason than this each farmer should strive to maintain a well managed woodlot.

*Water Supply.*—Forests at the head waters of streams regulate their flow. As has been said before, the amount of evaporation within the forest is much less than that outside because the loose litter offers little capillarity to the water content of the soil and also permits of a more rapid absorption of heavy rainfall. The water is then given out to the springs and streams in an almost constant supply.

*Erosion.*—The problem of erosion is a very perplexing one, especially in a rolling country. The unlimited removal of forests has left but little resistance to the flowing away of rainfall, for everywhere the soil is more

or less hard and compact. Water speedily runs over the surface, carrying soil and debris, which it deposits in the beds of streams. Places which wash badly are exceedingly common and cause the loss of much tillable land.

### THE MODEL WOODLOT.

After a review of the reasons for maintaining woodlots it is well to consider the organization of a model woodlot.

*Number of Trees.*—It should contain the number of trees consistent with the most rapid development of the best timber. Trees should stand close enough in youth to stimulate growth in height and to produce long, clear trunks. As the stand approaches maturity more and more space is required for each tree until at last probably only one hundred and fifty to two hundred trees of the original three or four thousand remain per acre. Thinning is brought about naturally by the struggle for supremacy.

*Distribution and Soil Cover.*—Trees should be evenly distributed over the entire area, always close enough together to prevent many direct rays of the sun from reaching the ground in summer, since the large openings give grass, a very dangerous enemy of forests, a chance to grow. The ideal soil is loose, porous, rich in vegetable mould and is covered with a thick mat of leaves and leaf humus to the exclusion of all grass and light-demanding weeds.

*Forest Cover.*—The trees which should be found in a woodlot depend upon two factors—(1) the economic value and (2) silvical characteristics. Such trees as black walnut, black cherry, ash, oak, maple and poplar have the greatest economic values. The other factor has to do principally with the soil, moisture and light requirements. For example, sugar maple requires rich upland soil and very little sunlight for its best development, while sycamore will grow on any wet soil if it has plenty of light. Thus we shall find in a model woodlot the species best suited to the soil, water supply and the uses to which the timber is to be subjected. In no case should there be any worthless species.

*Reproduction.*—In order to maintain the desired acreage of our timber producing area some efficient method of reproduction is necessary. This is usually found in the presence of large and mature seed-bearing trees, which scatter their fruits over long distances until they find lodgment in places suitable for germination. Another method of reproduction is by

stump sprouts or coppice growth. However, the size and quality of the timber produced in this way is much inferior to that formed from seedlings. For quick reproduction, advantage of this sprouting tendency should be taken in trees like the oak, basswood, catalpa and hickory.

### HOW TO REACH THE MODEL.

The next point to demand our attention is how to bring the existing woodlots into model conditions. The examination of this problem may be conveniently considered under three heads: (1) Protection, (2) General Improvement Cuttings, and (3) Improvement of Type Stands.

### PROTECTION.

The necessity for protection arises from the loss occasioned by grazing, fire, insects, fungi, wind and careless work in the woods.

*Grazing.*—Grazing injures a forest in two ways—by browsing and by trampling. Domestic animals browse sprouts and young seedlings, break off shoots and buds and gnaw the bark of trees. By the destruction of herbage the sharp hoofs of sheep cause loose soil to become looser and stiff soil to become more compact. Cattle and horses are much less harmful than sheep about trampling, although their hoofs frequently tear away small rootlets. This disturbance of the soil and soil cover seriously interferes with its water supply. In general the results of grazing make it imperative to exclude all stock from the woodlot.

*Fire.*—Fire is another great enemy of forests. The leaf litter and humus, young growth upon which the future supply depends, and mature trees are all affected. A single fire does not usually seriously injure older trees but a series of fires either burns them up completely or leaves them in such a weakened condition that they are blown down by wind or attacked by insects and fungi, and then furnish a source of infection for other trees. But in this thickly settled region fires are easily handled, for they can readily be seen and extinguished.

*Insects.*—The following conclusions regarding insect injury have been drawn from a careful investigation of the existing conditions throughout the state:*

(1) Insects causing the death of the tree:

(a) Found in extensive numbers and causing serious injury, as follows: Bark beetles on oaks, hickories and locust.

*Report of State Board of Foresty, 1907.

(b) Found in limited numbers and causing secondary injury as follows: Bark beetles on walnut, cherry, hackberry, elm, mulberry and ash; bark-boring grubs on oak and chestnut.

(2) Insects not causing the immediate death of the tree:

(a) Found doing serious damage to timber as follows: Carpenter worm on oak; wood borers on hickory; powder post borers on hickory.

(b) Injury to foliage: Nearly all species of trees found affected by one or more of the following forms, of which all except the cottony maple scale cause little damage: Leaf eaters, leaf miners, leaf rollers, saw flies, scale insects and gall flies.

The bark and wood borers can usually be detected by pits or deposits of fine sawdust around the holes. About the only remedy is to remove the infected trees at such times as will prevent the hatching of the larvae. Damage due to leaf insects is usually so slight that it may practically be disregarded.

*Fungi.*—Fungi attack trees in several ways. Some kill the roots, others grow upward from the ground into the trees and change the sound wood of the trunks to a useless, rotten mass or leave only a hollow shell. The spores of others come in contact with every part of the tree as they float about through the air. These spores find a very suitable place for germination if they fall on wounds. By removing infected trees and destroying old logs fungous diseases may be fairly well controlled.

*Wind.*—Wind-blown timber frequently exists in open or unprotected stands and in moist places where root systems are shallow. Trees weakened by fire, fungous and insect attacks are easily broken off. Of course the mature trees may be partially or wholly utilized. The greatest damage is done to those for which there is no immediate use.

Woodlots which have been unprotected from the time they were comparatively small usually have their own windbreaks made by the development of numerous side branches. A strip a few rods wide along exposed margins of woods should always be kept as dense as possible. The development of brush and undergrowth should be encouraged. Unless there are others to take their places no trees should be cut in this protective area

Should it be necessary to plant a windbreak it is best to employ two species, one a rapid grower to provide early protection, the other of slower growth to make a permanent and more efficient shield. Carolina poplar,

black walnut and catalpa are types of the first class, and any of the evergreens types of the second class. The spacing should be about four feet in rows six feet apart. At least half of the trees should be removed when they begin to crowd badly. When a good protection has been well established trees may be removed anywhere within the grove with practically no danger of windfall.

*Work in Woods.*—Another important thing to keep in mind is care while working in the woods. The object of management is to have new trees of the most desirable species to replace as soon as possible those which are removed. Therefore it is necessary to protect young growth. Care should be taken in felling trees not to injure others nor crush young seedlings. Brush should be piled in places where danger to timber from fire is reduced to a minimum.

IMPROVEMENT.

The second part of our examination, general improvement cuttings, deals with defective and infected trees, tree weeds and a general plan for harvesting.

*Defective and Infected Trees.*—Many woodlots contain stag-headed or entirely dead trees which are rapidly decreasing in value. They spoil the beauty of a grove as well as furnish a convenient place for beetles and fungi to live and propagate. They should be removed immediately.

*Tree Weeds.*—Tree weeds are another waste of our resources. A tree weed occupies space in a timber stand but has comparatively little value. Ironwood, water beech, dogwood, scrub oak, pawpaw and sassafras are examples. It is advisable to remove these as well as the dead, dying and infected trees at once unless by so doing large spaces are opened up in the forest cover which will not close before grass has a chance to start.

*Mature Cutting.*—One more general rule of improvement is in regard to cutting. Usually only such trees as have passed their maturity or the point where the amount of wood formed each year begins to decrease should be cut. And no more wood should be removed than is actually grown. Thus, if a woodlot is producing five cords of wood annually, it is better to cut five or only four cords than six. If a method like this is used and care taken to keep the ground fully stocked with thrifty young trees the woodlot may be kept up indefinitely.

*Coppice.*—In cutting the following suggestions should be kept in mind: Stumps should be cut low in order that the sprouts may become independent of the old root system as soon as possible; they should be cut smooth and slanting or have the sharp edges removed so as to prevent water from collecting on them, for in such cases they are apt to rot and infect the sprouts; care should be taken not to tear the bark from the stump since this often prevents buds from developing at the root collar; the sprout should be cut when the sap is down, early spring or late fall, for when cut in midsummer frosts are apt to kill the new sprouts which start up, before their growth is completed and their wood hardened.

MATURE OPEN STANDS.

*Character.*—Most woodlots are remnants of the original hardwood forest. The valuable straight grained and easy splitting trees have been cut for lumber or firewood. Those which remain have received no attention. They are mature, crooked, knotty or badly diseased and grow in clumps or are scattered over the lot. Few are of any value. Almost all these timbered tracts have been used for pasture, and as a result of constant grazing the ground is covered with a thick, heavy bluegrass sod to the exclusion of desirable young growth. If any reproduction does occur it is very irregular and is composed mostly of weed species.

*Treatment.*—The treatment of such stands depends upon the degree to which it has deteriorated, its location and the owner's need for timber. If it is on land better suited for agriculture and the farmer is more in need of fields than timber, probably the best thing to do would be to remove the timber completely and cultivate.

But if the lot is to be rejuvenated, the first step to take is to exclude all live stock. Should it be necessary to keep some of the woodland for pasture the thriftiest portions should be fenced off and most of the trees removed from the remainder. More timber and more grass can be produced separately than together. The next step is to remove tree weeds and other trees whose value is decreasing. The remainder will furnish seed. In order that the seeds may have the best possible conditions for germination the sod should be broken up by means of a bull-tongue plow or disc harrow. A rank growth of briars and weeds will probably spring up as soon as the sod is removed, but these make a very good protection under which the young seedlings are to develop. Soon the new growth kills out

the weeds and briars and rapidly establishes a good stand. Should other species than those present be desired it is necessary to plant them. As soon as reproduction is well under way the mature trees may be cut. Still it is a wise plan to leave some of them for seed and to furnish timber while the new crop is growing.

### IRREGULAR, UNEVEN-AGED STANDS.

*Character.*—It is from the irregular, uneven-aged stands that we expect the earliest good results. These are parts of the original forest retained in almost virgin condition. Some are dense, others more or less open. In them the soil is almost ideal, but not so with the forest. Fungous and insect hosts, old logs in various stages of decay, are scattered over the ground. Many of the trees are mature but in very poor condition. Some, however, are large and have long, smooth trunks and compact crowns. Increase in height has practically ceased and diameter growth is very slow. A young growth of various species, many of which are undesirable, fills up small openings made by fallen trees. On the whole the forest capital is slowly but surely decreasing, for the amount of timber produced annually is more than offset by death and deterioration of the overmature trees.

*Improvement.*—The first requirement for the improvement of this type is the same as for mature open stands; that is, the removal of tree weeds and the species undesirable for other reasons. The next process, thinning, is brought about naturally by shading. Trees which are crowded while young try to get their crowns into sunlight, and consequently produce long, slender stems. If, after a sufficient height has been reached, space is given for increased root and foliage development, an increase in wood production occurs. This increase takes place in diameter growth, since there is no longer any incentive for height growth. The purpose of artificial thinning is, then, to accelerate diameter growth as much as possible, to substitute for nature's wasteful struggle a systematic removal of weaker and inferior trees, leaving as many of the good ones as can develop without retardation for a given period.

*Thinning.*—This process requires considerable judgment and experience, for special attention is given to the trees which are to remain rather than to those which are to be cut. Of course the most valuable and rapid growing species take precedence over others. The following list will serve as a guide, although it is by no means invariable:

**Species specially favored**: oak, hickory, ash, black walnut.

**Species of less value**: yellow poplar, butternut, basswood, maple, elm, beech.

**Species usually removed**: ironwood, cottonwood, sassafras, water beech, etc.

The character of the tree is more important than the species. Tall, straight trees with well developed, thrifty top are left in preference to those which are spindling, weak-topped, crooked or unsound. In a group of equally good trees it is often best to remove one or more, for by so doing the remaining trees will produce more wood than all of them had they been left undisturbed. Trees with their crowns entirely exposed to sunlight are seldom removed unless a number of thrifty ones will be assisted. Those completely overtopped by others have ceased to be a factor in the growth of the stand and may be cut whenever their wood will pay for their removal. Another class of trees are those which receive sunlight from above but which have their sides shaded. It is in this class, where the struggle for existence is most severe and where the greatest economy of energy can be brought about, that most thinning is done. It is better to make light thinnings, never more than a fifth of the stand at a time, than to remove too many at once, for this opens up large patches of ground which dry out on exposure to sun and wind and furnish an excellent opportunity for the growth of grass and undesirable brush. It is not safe to say that this species must be removed to make room for that or that three sprouts must be cut from a group of six. All the improvement thinnings must be made upon the judgment of the operator.

In the woods which contain large open spaces here and there trees should be planted as in mature open stands. In any case growth of young trees and shrubs should not be hindered but rather encouraged on a strip at least two rods wide. A windbreak should be planted if necessary.

### YOUNG STANDS.

*Character.*—The third type of woodlots is the young stand. The ground, seeded by the trees left after all merchantable timber was cut, has become covered with second growth trees four to twelve inches in diameter and twenty to fifty feet in height. Many of them are straight and thrifty, but many more are gradually being suppressed and are dying. Trees in little groups here and there which started from seed the same year are so evenly matched in size that growth is temporarily arrested.

*Care.*—The seed trees which determined the composition of the young stand are becoming useless through decay and other defects. Often there are grape vines, old fire-scarred snags and other material with which the lot could well dispense. These should be removed. At the same time a thinning could profitably be made if the stand is too thick. The aims and results of thinning have already been discussed.

PLANTING.

Under this subject the main points of planting and growing woodlots are mentioned for the benefit of those who wish to have more timber than can grow on the land already forested.

*Location.*—In general not less than one-eighth of a farm's total area should be in woodland. Some have more than this amount, but many others have practically not a single acre in woods. As has been said before, the woodlots existing at present have little, if any, relation to farm buildings. A little corner cut off by a stream or railroad, or land otherwise unfit for agriculture because of steepness, rocks, etc., furnish a place to plant a woodlot. It would be well if these so-called waste portions were so situated that timber growing on them could form a windbreak. This idea of protection should always come into consideration when preparing to plant.

*Species.*—Whatever the opinions of individual nurserymen may be regarding the species to plant, there will never be found trees better suited to any region than those which are natural to its soil. For central Indiana we recognize white oak, red oak and burr oak, ash, walnut, hickory, sugar maple, black cherry and elm as types for lumber; and osage orange, black locust, coffee tree, catalpa, etc., as types best suited for the production of posts, poles and ties. Careful examination of the soil should also be made, and only such species which will develop best under the existing conditions should be planted. These two points were brought out fully under the topic "Forest Cover" in "The Model Woodlot."

*Preparation of the Ground.*—The ground should be plowed, harrowed and worked into as good condition as for any agricultural crop in order to secure the best results. However, it is not necessary to prepare it so carefully. Planting has frequently been done with good results on burned over woodland according to the third method described below under "Planting." But trees growing on well prepared ground have as much

advantage over those on unprepared as has corn under the same conditions.

*Where to Procure Seedlings.*—The farmer may grow his own trees from seed, procure wild seedlings or purchase from a nursery. Wherever possible wild seedlings are much cheaper. They are weaker than nursery grown stock, and should be transplanted to a nursery for one or two years before being planted in the field.

*Care of Trees Before Field Planting.*—Trees should be planted with as little exposure of their roots as possible, for the root hairs, upon which the tree depends for taking in its food supply, will dry out and shrivel up when exposed to dry atmosphere for even a few minutes. Some of the broad-leaved species can withstand this drying out if they receive proper treatment afterwards. The best way to prevent this is by "puddling." A "puddle" is a mixture of earth and water about as thick as cream. It may be mixed in buckets, tubs or barrels and drawn along where trees are being dug up so they can be plunged into it immediately, or, if the seedlings have been received from a nursery, as soon as they are unpacked. If planting is to take place at once the trees may be carried to the field in the "puddle." But if some time is to elapse before planting they should be "heeled in" as they are "puddled." For "heeling in":

Dig a trench deep enough to bury the roots and part of the stem. The trench should run east and west, with its south bank at a slope of about thirty degrees to the surface of the ground. A layer of trees should be placed in the trench on its sloping side, the tops toward the south. The roots and stems should be covered with fresh earth dug from a second trench, in which a layer of trees is put and covered in the same way. The digging of parallel trenches is repeated and layers of trees put in until all have been "heeled in."

*Time for Planting.*—The best time for planting is just before growth begins in the spring. At such a time the seedlings are apt to receive the least injury. In general the frost should be out of the ground. Frost is one of the chief dangers of fall transplanting, for the young trees are often heaved out of the ground as it freezes. It is also best to choose a wet or cloudy day for transplanting.

*Methods.*—After everything has been made ready for planting the ground should be marked out in rows four, six or eight feet apart, depending on the species, character of the soil and length of time cultivation is

to continue. The methods of planting are very simple. The best perhaps requires two men. One carries a bucket of "puddled" seedlings. The other carries a spade which he sets full length in the ground. He then pushes the handle forward, sticks a seedling, which the first man hands him, in behind the blade, withdraws the spade and then steps firmly with both feet on the ground around the tree. Another rapid method which often succeeds is to plow a furrow, lay the trees against the side of it, cover with a hoe and tramp firmly. The remainder of the furrow may be filled by means of a cultivator. A third way is to dig a hole with a grub hoe or mattock. This method is used only on unprepared ground. The size of the hole depends upon the size and character of the root system. Fine dirt is then thrown in next to the roots and the hole filled up, the earth being firmly tramped as before. All trees should be planted deep enough so that when the ground settles they are covered to the same depth they were before being transplanted.

*Cultivation.*—One of the great troubles with the plantings already made in central Indiana is that they have not received sufficient care. They have been plowed or hoed a few times and then left to take care of themselves. The methods and aims of cultivation in the state reservation are given in the following:

"The cultivation given the young trees growing in the regularly planted fields was of two forms, plowing in the same manner that corn is cultivated and by hoeing. In some fields the trees were plowed and hoed, while in others they were simply hoed without plowing. They were given two complete cultivations. One plan seems to be as successful as the other. The aim sought by the cultivation was to keep down weeds and other wild forms of growth that might overcome the young trees. In the fields where the soil around the young trees was kept loose and free from weeds for a short distance from the trees (eight to twelve inches) by hoeing, and the other forms of growth permitted to stand around them, the young trees seemed to do the best. The only reasonable opinion that can be given for this fact is that the other growth formed a mulch over the soil and prevented evaporation and also a forest condition of shade and protection which resulted in good to the trees, and by keeping a clear opening around them prevented them from any smothering out, as will occur where the weeds and other growths are permitted to grow up close around them. The young trees in such fields are larger and have better

boles formed than those growing in the fields where more complete cultivation was performed. Those growing in the more open fields and where the most complete cultivation as to keeping the soil cleaned of all forms of outside growth seemed to grow more bushy and to cease growing earlier in the summer than the others. The only reasonable opinion to be given for this fact is that they were more exposed to the heat of the sun, nothing formed a covering to the soil to prevent evaporation and the trees were deprived of any sort of shade protection. No forest influence was thrown around them. . . . .

It must not be inferred from the discussion of the cultivation here given that no cultivation is needed. The young trees must be given cultivation necessary to protect them from weeds and other wild forms of growth immediately around them. . . . . The trees at the reservation are given the cultivation that can be performed with the means supplied, and no more. If more means were provided they would be cultivated more and better results might accrue."

It can be seen that the Board of Forestry recognizes the fact that they are not caring for the young trees in the best possible manner. A crop of weeds is not the best way to prevent evaporation from the soil. The maintenance of a dust mulch by cultivation will do this and will not use food material stored in the soil. A disc harrow or a five-toothed cultivator run through between the rows after each rain during the summer will keep up the dust mulch and keep down the weeds. In other words, a forest crop should be cared for just as a corn crop, except that the period of cultivation is longer, sometimes three or four years.

*Thinning.*—The maximum number of trees per acre at maturity is about two hundred. It has already been shown why thinning is beneficial, so only this remains to be said: a few years after the plantation has become well established the process of thinning should begin. The weakest and poorest trees and those crowding better ones should be removed here and there to make room for their more vigorous neighbors. Gradually this process should continue, the material being utilized, until at maturity the woodlot has the requisite number of good trees and also has provided for a permanent supply.

## DOES A WOODLOT PAY?

The question naturally arises, Is a woodlot a paying proposition? If it is not, why are the most progressive farmers taking such an interest in forest planting and forest management? Timber is a necessity. In earlier times it was not so valuable, so the land was cleared. The remnants of the old forest may easily be improved at odd times. The cost is much reduced if the farmer does his own work. So it is with planted woodlots, especially if wild seedlings are used. Besides, the price of timber is advancing as the supply is diminishing. This alone encourages planting.

The following extract from a letter shows that with a little care a woodlot can be made to pay:

"I have logs enough cut now to make from forty to fifty thousand feet of lumber. These logs I cut from a ten-acre grove that was only a brush patch thirteen years ago. In addition to the logs the grove has supplied plenty of wood for from two to four stoves, and some for sale, besides posts and poles, all of which came from the thinnings. There are still enough trees on the land to make a good grove." The present generation may not reap the profits but the next one will.

## SUMMARY.

The following conclusions have been drawn from this study:

1. The present woodlots, only the remnants of the early forests, are in very bad condition.
2. Well-ordered woodlots are valuable financially, climatically and aesthetically.
3. Old woodlots may be improved and new ones planted successfully.
4. Woodlots must be protected and well cared for in order to secure the best results.
5. A woodlot is a paying investment.

The one thing lacking is universal interest.

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Crawfordsville, Ind.

## LIST OF USEFUL PUBLICATIONS.

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all, Wm. L. Practicability of Forest Planting in the United States. Reprint from the Year Book of the Dept. of Agriculture for 1902.

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ellog, R. S. Forest Planting in Western Kansas. U. S. Dept. of Agriculture, Forest Service. Bulletin 52.

homas, M. B. Forestry in Indiana. Reprint from the Indiana Academy of Science. 1901.

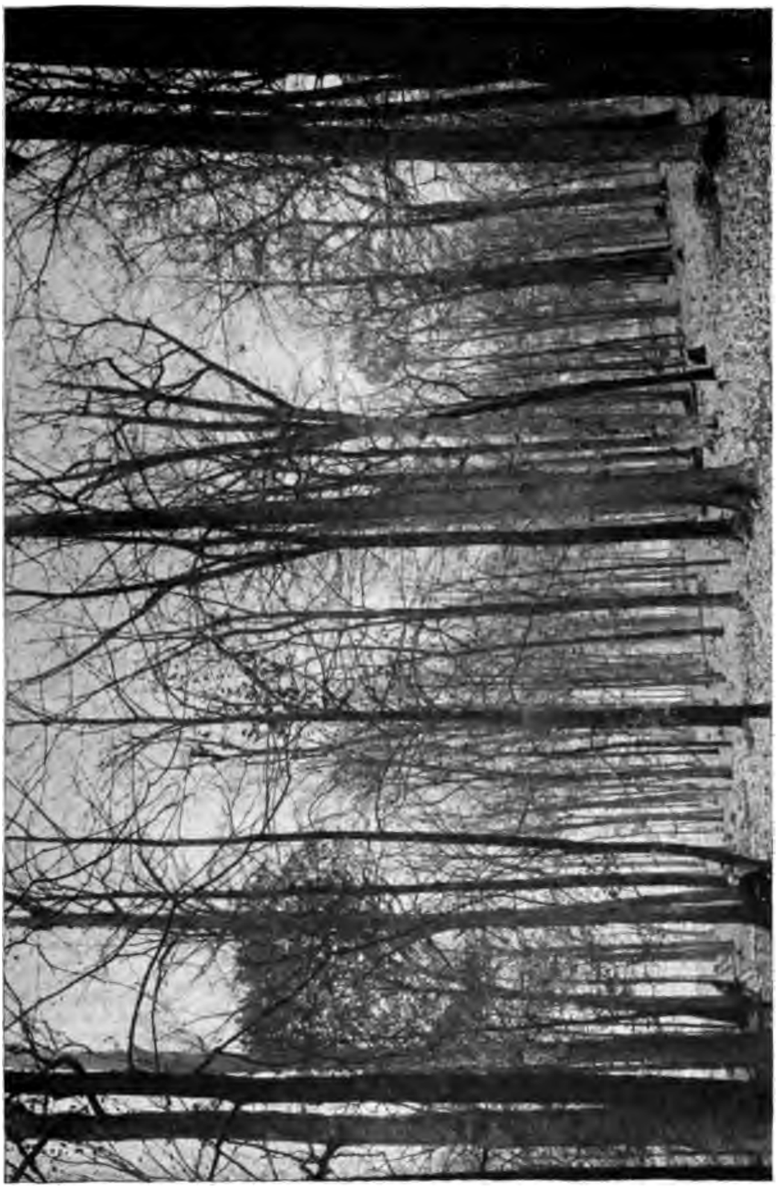
ublications of the Forest Service:

Suggestions for Forest Planting in the Northeastern and Lake States. Cir. 100.

How to Cultivate and Care for Forest Plantations on the Semi-Arid Plains. Cir. 54.

How to Transplant Forest Trees. Cir. 61.

No. 1. An irregular stand in almost virgin condition. The owner will not allow a single tree to be cut. The fallen trees, decaying logs and accumulating underbrush indicate waste. This is not forestry, but neglect.



**No. 2. A mature open stand. The ground is covered with a thick growth of grass, a great enemy of reproduction.**

No. 3. A young stand of hickory about fifteen years old. All the grass has been tramped down and killed under the large black oak on the right. This would make a good grove if the cattle were excluded and the growth of seedlings encouraged.

No. 4. The usual evidence of neglect of the woodlot. Pasturing has destroyed the young growth. The mature trees not needed for seeding should be cut. The fallen timber should be taken out and saved. Unless the stand is thickened, the young growth will be low branched and worthless.

# Recent Work in Wood Physics.

By William Kendrick Hatt.

(Abstract.)[1]

The new series timber tests of the Forest Service, which constitutes the most important recent series of experiments, was begun in 1902 under the direction of Mr. Gifford Pinchot, Forester, Forest Service, United States Department of Agriculture. About 44,000 test pieces have been tested.

These timber tests are divided into two parts: Class (a). Tests on market products of actual size, in which characteristic defects occur, such as stringers, vehicle parts, railroad ties, of interest and value to engineers and manufacturers. These correspond to tests on riveted joints or built-up structures in metal testing. Class (b) includes so-called "scientific" tests of small, perfect specimens with uniform moisture content, representing material collected from the forest, in which the strength is related to the physical structure and position in the tree. These tests are of especial value to the botanists and foresters and aid the solution of silvicultural problems.

A summary of results obtained to date will be presented.

### INFLUENCE OF CONDITIONS OF TESTS UPON RESULTS.

(In these studies small, perfect specimens are used).

1. *Speed of Test.*—The strength of wood varies significantly with the speed at which stress is applied. increasing more rapidly as the speed increases. Tests are standardized for speed[2] on the basis of fiber strain per unit of time; and experimental factors obtained to adjust strength values from one speed to another. The adopted standards of fiber strain are as follows, expressed in inches per inch per minute:

| | |
|---|---|
| Large beans | .0007 |
| Small beams | .0015 |
| Compression parallel to grain, small pieces | .003 |
| Compression parallel to grain, large pieces | .0015 |

[1] Abstracted from paper by the author, read before the Copenhagen Congress of the International Society for Testing Materials.

[2] See Proceedings American Society for Testing Materials, Vol. 8, 1908, page 541. "The Effect of the Speed of Testing upon the Strength of Wood and the Standardization of Tests for Speed," by H. D. Tiemann.

Strength of wet or green wood is much more sensitive to changes of speed than is dry wood. At the speed adopted for official tests a change in speed of 50% may ordinarily be allowed without causing a variation in strength of over 2%.

2. *Temperature.*—Since wood is a more or less plastic substance it is sensitive to changes of temperature. Tiemann's[3] experiments show that soaking certain species in water at normal temperature does not affect their strength. It appears, however, that warm water has a marked weakening effect. The extreme condition is when wood is made pliable by boiling. Some woods are no doubt more sensitive than others to the effect of temperature of the water in which they are immersed. In recent tests made in winter weather on red oak (Quercus Rubra) ties at Purdue Uuiversity, ties taken from the temperature of the storehouse (about 25° F.) were from 9 to 17 per cent stronger than those tested at the temperature of the laboratory (about 70° F.). Probably this marked difference in strength is to be found only in case of green or wet wood. The rupture work is not affected to the degree of the ultimate strength. Hickory seems specially sensitive to change of temperature. It is concluded that the ordinary temperature variations of the air of a laboratory are not important, but that the temperature of the storehouse may render it necessary to warm the wood. In fact, the effect of a given factor on the strength of timber, or difference of strength of two species, may at times be entirely masked by variations of temperature of timber at the time of test.

3. *Moisture.*—The effect of moisture on the strength of wood has been thoroughly investigated by Tiemann.[4] His material was small test pieces uniform in moisture content throughout the cross-section; and he determined the distinct "fiber saturation" point, above which increased moisture content did not affect the strength of timber and below which there was an increase of strength. Previous experiments, yielding a continuous moisture strength law, were apparently made with "case-hardened material."

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[3] Bulletin 70. Forest Service, 1906. "Effect of Moisture on the Strength and Stiffness of Wood," by H. D. Tiemann.

[4] Bulletin 70. Forest Service, 1906. "Effect of Moisture on the Strength and Stiffness fo Wood," by H. D. Tiemann.

Circular 108, Forest Service, 1907. "The Strength of Wood as Influenced by Moisture," by H. D. Tiemann.

##### RELATION OF TESTS.

The relation between the strength under various kinds of tests, such as shear, bending, etc., and compression parallel to the grain, have not been determined yet by an analysis of the data. It is doubtful if any one test can be used to predict the strength of the material under other forms of tests when conditions vary with respect to previous heat treatment, moisture, drying or preservative treatment. For instance, brittleness induced by overheating is evident in impact tests, but this will not necessarily be evident from the compression test parallel to the grain.

An investigation of the effect of speed of test is a part of the general study of behavior of wood under three conditions of loading:

(a) Dead or constant load.

(b) Ordinary static test with increasing load.

(c) Impact test.

(a) Dead load tests exhibit the plasticity of wood. Nearly all deformations increase with duration of load, but the deformed beams subsequently tested show no loss of ultimate strength. Deflection brought about by humid atmosphere is not recovered by subsequent drying. The question is often asked: "What per cent of the load, as determined by the ordinary static test, will break a beam if left on indefinitely?" This has no answer.

(c) Under impact loading, wood will submit to greater elastic deformation than under the ordinary static tests. Impact bending tests show elastic deformation largely in excess of those experienced under static load. The impact test is made under increasing height of drop.[5] The order of resistance of air dry woods at the ultimate failure strength, so far obtained is as follows:

Hickory, Longleaf Pine, Douglas Fir, Loblolly Pine, Chestnut, Spruce, Yellow Poplar, Western Yellow Pine, Western Hemlock, Sugar Pine, and Coast Redwood.

(d) *Abrasion Test.* The abrasion test is under study.[6] Wood is worn by sand-paper in the Dorrey Machine.

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[5] Circular 38, Revised, Forest Service. "Instructions to Engineers in Timber Tests," by W. K. Hatt.

[6] See American S. for T. M., Vol. 7, 1907. "P. U. Impact Testing Mach.," by W. K. Hatt.

INFLUENCE OF TREATMENT PREVIOUS TO TEST.

(a) Drying in Hot Air, Steam, Saturated Steam, etc. A research is under way to investigate the safe limits and the most advantageous conditions for the commercial processes of drying wood. The immediate strength after drying is of course, usually greater because of the lessened moisture content. It is now apparent, however, that all processes of drying wood, even air-drying, are attended with weakening of structure, so that when the dried wood is resoaked there is a loss in strength of 10%, and generally more. The drying of white ash (Fraxinus americana,), for instance, at 145° F. in either dry air or exhausted steam, or in superheated steam at 312°, caused no significant loss in strength in the air dry condition, but the resoaked wood was considerably weaker than the green wood. Under 20 to 30 pounds of steam applied during 1 to 4 hours, pine and ash suffer but little loss in static strength after the moisture from the steam is removed by air drying. At higher steam pressures (above 50 lbs.) large and permanent losses result. An equal amount of dry heat is less injurious to wood than moist air or saturated vapor, whenever the temperature exceeds 212° F. The hygroscopicity of the wood in the air-dry condition is reduced by the process of drying in steam, dry-air or saturated steam. Microscopic study shows that the cell walls split open because of the shrinkage of these walls when they begin to dry out.

The results from the Drying-Strength Study are not sufficiently advanced to allow complete conclusions.

(b) *Treatment with Preservatives.* Tests at the Louisiana Purchase Exposition[7] established the safe limit of steaming for seasoned loblolly pine to be 30 lbs. applied for 4 hours, or 20 lbs. applied for 6 hours. Burnettized loblolly pine ties exhibited some degree of brittleness under impact test. Creosote appeared to act upon the strength in the same way as water. It retards the seasoning of timber, with beneficial results to its physical condition. Present evidence points to steaming, or effect of heat in preliminary seasoning, as the only dangerous element of the treating process. The proper limits of heat should be determined for different species of timber.

In the case of bridge timbers, of coniferous species, of large size, incomplete evidence indicates that the desired penetration of creosote can

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[7] Circular 39, Forest Service. Experiments on the Strength of Treated Timber," by W. K. Hatt.

only be obtained by cylinder processes that reduce the strength of the timber. The unit stresses used in the design of creosote structures should, therefore, in these cases, be decreased below standards established for natural wood.

### UNIT STRESSES FOR DESIGN.

The relation of strength of large sticks, involving defects, to small and perfect pieces, taken from the parent beam, is reported in Circular 115, Forest Service. The strength of large and small sizes is not a question of geometrical magnitude, but of the existence of defects in the large sticks such as knots, shakes, checks and the presence of inferior growth.

Study has been given to the failure of large beams under longitudinal shear. It is apparent that, in the case of large beams of seasoned timber, the failure is due to longitudinal shear rather than to bending. In green beams, also, this form of failure is frequent. Therefore, shearing stresses should be taken account of in the design. The result of later tests confirm the early results that the strength of large pieces is not increased by subsequent seasoning, except in case of select grades. In other words, unit stresses for design should usually be based upon strength of green timber.

### NEW SPECIES AND SUBSTITUTES.

The eucalypts of California and the South have been tested. They are among the strongest of our woods. The quality of the various species differs greatly, varying in kiln dry state from 25,000 pounds per sq. in. to 13,000 pounds per sq. in. in modulus of rupture. Tests have been completed on tan-bark oak, which formerly was left stripped of its bark in the woods.

### GENERAL STUDIES OF SPECIES.

Tests of red gum are completed.[8] Tests of various species of hickory collected from various site conditions have been made and the report completed. These latter tests established relations between rate of growth and strength, locality and strength, and species and strength. It appears that the most fundamental factor governing the strength of wood of any species is the specific gravity, or, in the conifers per cent of summer wood.

[8] Bulletin No. 58, Forest Service. "The Red Gum," by Alfred K. Chittenden.

*Technical Problems.*—The study of track fastenings, including [illegible] and screw spikes, and tie plates, and the relation of these to the strength of ties is in progress. Laboratory tests are supplemented by service tests in tracks of railroads under operation.

TECHNIQUE OF TESTS AND THE ORGANIZATION OF THE LABORATORY WORK.

The methods and records and organization are now well developed. The results of experience for the past six years are contained in Circular 38, (Revised), entitled "Instruction to Engineers in Timber Tests." Recently a department of microscopic examination of wood has been added to study manner of failures in the tissues, changes in structure resulting from heat treatment, location of preservative fluids and allied problems.

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# Forest Conditions in Indiana.

By Stanley Coulter.

Certain economic statements may serve as a suggestive introduction to this study of Forest conditions in Indiana. Some of these will be more fully elaborated later in the paper, others need no comment since their mere statement is sufficient to call attention to existing conditions.

A reference to the Census report of 1880 will show that at that time Indiana ranked sixth in the list of lumber producing states. In 1908 it ranked twenty-seventh.[1] Not only had it fallen to this low position in the list of lumber producing states, but the cut of 1908 was very decidedly less than that of 1907. While some part of this latter loss may be attributed to the reduced demand for lumber in 1907, all of it cannot be so referred. As a matter of fact the cut made represented all of the high grade timber upon which lumbermen could lay their hands.

While certain regions of the state, notably in the southern counties, still appear to be heavily timbered, an examination shows that practically all forms of high value have been cut from them. They have been swept clean of their yellow poplar, white oak, black walnut, and cherry and are made up almost entirely of what may be regarded from an economic standpoint as second grade or inferior forms. It is these inferior forms that are furnishing the future forest, if indeed there is any promise of a future forest. The splendid forests of the past,[2] splendid not only in extent but in the quality of the timber they yielded, have disappeared and the forests that remain are infinitely inferior to them both in extent and quality. Present conditions indicate a still further deterioration unless prompt remedial measures are taken.

A rather careful examination of the existing areas, supplemented by the opinion of lumber buyers, leads to the conclusion that few extensive areas in the state will show a stumpage of desirable forms exceeding 2,500 feet board measure. My own judgment is that the average stumpage

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[1] Forest Products No. 2. Lumber, Lath and Shingles, 1908. Bureau of the Census, issued November 15, 1909, p. 8.

[2] Stanley Coulter. The Forest Trees of Indiana, Trans. Ind. Hort. Soc., 1891, p. 8. A. W. Butler. Indiana: A Century of Changes in the Aspects of Nature, Proc. Ind. Acad. of Sci., 1895, pp. 32, 33.

is below this figure. In order to reach this estimate it has been necessary to include beech, elm, and sycamore, species which for various reasons are not to be classed with white oak, yellow poplar and black walnut. Indeed the eager search for beech and elm is a fairly conclusive evidence of the paucity of forms of higher quality in the forests of the state. Of course there exists here and there throughout the state small tracts showing a heavy stumpage of high grade species, but such areas are the exceptions that prove the rule.

A constantly increasing number of wood-working plants are shutting down because of inability to secure the needed raw material. The radius marking the limit from which this raw material can be drawn is very definitely limited by freight charges. I have received a statement, which may be considered as official, that fifty per cent. of the veneer plants of the state are shut down because they are unable to secure logs suitable for their work. What is true of the veneer industry is true in varying degree of other wood-working industries. This means, unless checked, loss of employment to hundreds or even thousands of men, and either a removal of capital to other states or its absolute loss. The reduction in the number of wood-working plants in the state within the last decade has been startlingly large and can only be explained by the rapidly waning supply of suitable raw material.

While the data in my hands are not yet complete, I have records of over five hundred thousand (500,000) acres of waste land in the state. This waste land, located in a very great measure in the southern portion of the state, is the result in almost every instance of destructive lumbering. Concerning this conclusion there can be no doubt. We have knowledge of former forestal conditions, and in many cases the history of the cuttings of specific tracts. These waste lands lie open and are absolutely waste; they are not used in agriculture or horticulture and have wasted to such an extent that they are completely abandoned. They yield revenue neither to the owner nor the state. The indications are that the amount of deforested land abandoned by the owners is constantly increasing. The surest, indeed the absolutely unmistakable sign of a decadent state from an economical standpoint, is a constant increase in the area of abandoned lands.

To counteract the conditions indicated in the preceding paragraphs, tree planting has been undertaken in the state on a fairly large scale within

the past few years. These plantings have been made by individuals and by corporations. The tree plantations run up into the hundreds and the number of trees into the hundreds of thousands. A careful inspection of sixty-nine of these plantings, embracing two hundred fourteen thousand (214,-000) trees was made in 1908-09 by Messrs. U. C. Allen and H. C. Kennedy. The plantations examined covered the state with the exception of the southeastern counties and represented practically every type of soil and drainage conditions. Supplementing their records by my own observations and those of Secretary C. C. Deam of the State Board of Forestry, I am led to the conclusion that afforestation operations in the state have been, in a large measure at least, unsatisfactory. While there are occasional instances of successful and apparently profitable tree culture in the state, it is very certain that, taken as a whole, the results are not of such character as to give promise of any relief from present conditions in the immediate future. The plantings have been chiefly catalpa and black locust. Only in exceptional cases, and then rather as the result of chance than a definite purpose have other species been tried. A very few small plantings of black walnut and white ash practically represent the attempt in growing trees of high grade.

The reasons for these unsatisfactory results are not far to seek. They may be grouped under three categories:

1. Ignorance of the silvical qualities of the species.
2. Poor seed or seedlings which were not of the species desired.
3. Ignorance of the cultural requirements for securing rapid and healthy development.

Apparently in many of the plantations no question as to the fitness of the soil, or drainage, or exposure entered. In another large series of catalpa plantings the larger number of the trees were not the hardy catalpa *(speciosa)* but *C. bignonioides* or some hybrid. In more than one-half of the cases absolutely no attention was given after the planting, to cultivation, to pruning or to coppicing. A study of the conditions in these plantations is sufficient proof that afforestation operations will not be successful in Indiana until a much fuller knowledge of the silvical qualities and requirements of the species selected becomes common property.

Bad as the existing conditions are, the case is far from hopeless. The aggregate timbered area of the state is still large and while the stumpage is not heavy nor the quality all that could be desired, yet these areas

furnish not only the hope but the assurance of the future, if, *and only if*, they are intelligently managed. All of the timber lands in the state, with the exception of the State Forest Reservation, is held by private owners. As a rule these holdings are relatively small and our forests may be considered as made up of a large number of wood lots. It is a fact that cannot be too often repeated or over emphasized, that it is a much more certain and a much cheaper process to maintain and improve an existing stand of timber than to produce a new one by planting. Not only is it much surer and cheaper, but it is also much more rapid.

The problem of the future of the forests of Indiana is merely the problem of securing the proper handling and care of the wood lots and small timbered areas held by individual owners. If such areas are wisely handled and conservatively lumbered there is no reason why they should not for years yield a steady and increasing income and at the same time show a marked increase in quality and value. In other words the problem of the future timber supply in the state is very largely a problem of education. Owners of timbered tracts must be brought to a realization of the value of such holdings and trained in methods of management which will secure the results indicated. It must be shown also that such methods of management are profitable, for unless this can be done no method, however theoretically desirable it may be shown to be, will ever come into general use. The real peril lies in the fact that this process of education is a very slow one and that existing timber areas may be greatly reduced in value or completely destroyed before a knowledge of the better methods has become common property. An examination of a number of such tracts covering many counties of the state indicates fairly well what may be considered the average condition of the forests of Indiana today.

Almost without exception these timbered areas are used as pasture land, and have, in most instances, been so heavily overpastured as to practically destroy all prospects of the regeneration of the forest after the removal of the present trees. An examination of seventeen such wood lot pasture tracts during the past season which were distributed through twelve counties of the state, revealed the fact that in not a single one could any young seedlings or healthy, well formed saplings be found. Any system of management under such conditions is perfectly useless. Unless the condition of the wood lot areas is improved and the regeneration of the forests provided for by an abundant and vigorous growth of seedlings, the end of our forests is not far distant.

In most instances the withdrawal of the tract from pasturage will be sufficient to permit an immediate springing up of sufficient seedlings to care for the future of the tract. This withdrawal from pasturage should be absolute until such time as the young growth is beyond danger from browsing animals. After that time light grazing may not be injurious, although if grazing is permitted at all, there is the constant temptation to overgraze.

The effect of this overgrazing is very easily demonstrated by simply enclosing a tract which contains no seedlings, thus protecting it from cattle. Almost invariably a dense and abundant undergrowth representing many species of tree forms will spring up and in a few years will have provided a stand sufficiently dense to allow improvement cuttings and thinnings, leading to the formation of a new forest.

In the State Reserve a large acreage was burned over the year before the State took possession of the tract. At the present time, some eight years after the fire, the tract which was burned over is densely covered with a growth of vigorous and healthy young trees, with valuable species represented in such large numbers as to give certain promise of a fine even-aged stand after the cleaning and thinning cuttings have been made. The area was regenerated from adjoining seed trees. No treatment of any kind was given the tract; it was simply freed from pasturage.

In the hill regions of the southern counties, and especially in localities where the hills faced the Ohio river, the forests were removed many years ago. For years such tracts were left unfenced and during those years the land wasted through erosion and no seedlings obtained a foothold. At a later period when laws forbidding stock running at large were passed and when wire fencing came into general use, these denuded hills were quickly covered with a dense growth of vigorous young trees. No planting had been done, the soil had received no treatment, but the tract as in the former case was freed from pasturage. Such instances could be multiplied almost indefinitely and from them can be drawn a conclusion of high economic value, namely, that very many of the denuded areas of the state could be afforested by the simple process of relieving them from the burden of pasturage. It is safe to say that 90% or more of the timber areas of the state are so heavily over-pastured as to preclude any possibility of their future improvement or growth. Until the owners of these small forest tracts realize the utter destructiveness of over-pasturage but little

can be done to improve forest conditions in the state. That these statements are not exaggerated is a matter of fairly easy demonstration by any person who will go through an average forest in his vicinity and make a close examination for the young trees which stand as a prophecy of the future forest. In almost every instance they will be found to occur in such small numbers as to indicate a constantly waning forest. Indeed, in very many cases not a single seedling or sapling of a desirable species can be found.

A further examination of these areas within our state shows that in by far too many cases they have suffered damage by fire. In very many instances these fires have spread into the timber tract from the right of way of railroads or from meadow fires which have been started for the purpose of cleaning and have escaped control. However they may have originated, their effect upon the forest has been two-fold. First, in a serious damage to the mature trees and second, in practically obliterating all the young growth which may have become established. As a result of the action of such fires, not only is the young growth killed but the soil is placed in such condition as to preclude a future growth for several years. The damage by forest fires in the state during the past year, which was by no means an exceptional one, amounted at a conservative estimate to at least $100,000. A very large part of this loss could have been avoided by exercising ordinary care. Very much more of it could have been prevented by the rigorous application of the laws fixing the responsibility for the occurrence and spread of forest fires.

The value of these wood lots as they stand might also be very greatly improved in many cases if improvement cuttings of various kinds were undertaken. Almost all of them need "cleanings" in order to remove from them various undesirable forms. It must be remembered, however, that such cleanings must not be too vigorously undertaken lest too great an amount of soil be exposed to the action of the sun and the wind. Sudden changes in ecologic conditions are particularly fatal to young tree growth. Where the undergrowth or undesirable forms are at all dense, probably not to exceed 25% should be removed at any one time and the ground should not be cut over again in less than four or five years. In these cleanings the object should be to remove all forms the absence of which would improve the forest and give the trees left standing an opportunity for a more perfect development. In this cleaning should ultimately be removed

all trees, which, even if allowed to reach full maturity, would never have an economic value. It should also include all trees that are dead or dying, since such trees are not only deteriorating in value but also serve as centers from which various diseases destructive to the forest may spread, and because in addition they furnish natural breeding places for many species of harmful insects. When such dead or dying trees are infested with fungus diseases or injurious insects, they should be completely burned. The cleaning should also include all trees which are over-mature or for any cause are losing value. Trees which are undesirable in shape or from other causes do not promise to make a satisfactory growth should also be included in the cleaning. Special attention should be paid to seed bearing trees of undesirable species. These should be removed whenever found in order to prevent their seedlings from occupying the ground at the expense of the more desirable forms.

As has been suggested, these operations must not be carried on too vigorously since the young seedlings, which are to make the future forest, require shelter from the wind and from the sun during their earlier years and if the removal of these undesirable forms is made too completely at a single operation the object in view will be defeated. By the application of such methods not only may the condition of the wood lot be constantly improved so that in the end it will contain a vigorous and healthy growth of valuable forms, but at the same time much material which may be utilized for fuel and for other purposes will have been removed from the area. In almost every instance, if care is taken, these cleaning cuttings will more than pay for the expense required to make them. It is a conservative statement to say that over one-half of the existing wood lots in the state would be very greatly improved in value and in productive capacity by a series of judicious cleanings.

In addition to these cleaning cuttings, in certain regions "thinnings" seem to be required. Two trees of a valuable species may stand so close together that if both were allowed to remain, neither would develop into a good tree. One of them should be cut away. In almost every wood lot also, there are to be found clumps of trees which stand so close together that they have developed thin, weak stems instead of stout and sturdy trunks. Enough of these should be cut out to insure a healthy and vigorous growth on the part of the trees that remain. The thinnings differ from the cleanings in that, while the cleaning removes undesirable and injur-

ious forms only, the process of thinning removes desirable forms where they are wrongly placed in order that the trees left standing may have a better chance. There is scarcely a wood lot in the state in which manifold instances of the value which would result from careful thinning cannot be found.

The existing wood lots can be still further maintained in good condition by a more careful use of the material which is cut from them. There is a constant tendency to cut such trees as will work up most easily, whatever may be the purpose for which they are to be used. Good straight white oak of sufficient size to have a high value for lumber is cut for fire wood, or rails, or posts, when a score of other species which have no lumber value might serve these purposes as well if not better. In the same way large numbers of vigorous and straight young saplings are cut down for hoops, for poles, or for other of the manifold uses of the farm. Such wastefulness under present conditions is little short of criminal. The woods of high value should be allowed to come to their full size and development and the ordinary uses of the farm supplied from inferior timbers which are of less value and of less general usefulness.

Great care should also be taken in working up the tops of the trees cut in such a way as to utilize them as far as possible. Not only does such utilization reduce the number of trees that are cut from the tract, but it at the same time protects it from damage by fire, since the dry tops of trees burn fiercely and are always a great peril in case of fire. An examination of an ordinary cutting whether for wood or lumber or clearing will show that scarcely 50% of the tree is utilized.

It is very difficult to form any estimate of the amount of the present timber stand of the state. As contrasted with the past the average amount per acre has been very largely reduced. As examination of the sources of supply of wood manufacturing plants will show that a large proportion of the more valuable timbers which they use in their work are secured from without the boundaries of the state. As an illustration, information derived from certain veneering companies of the State may be given.

The Indiana Veneer and Lumber Company uses in its operation oak and principally white oak. Most of this is derived from the states between Ohio and Missouri, but not above 25% of it is secured from Indiana.

The Evansville Veneer Company cuts gum, poplar, white oak, red oak, sycamore and beech. They purchase these woods in Tennessee, Kentucky, and Mississippi, getting none from Indiana.

The Goshen Veneer Company uses bass wood, maple, ash, elm, sycamore, beech, poplar, oak and walnut. The oak they buy in Illinois and Kentucky; the poplar south of the Ohio river. As nearly as they can estimate, 60% of the material which they use comes from Indiana.

The Hoosier Veneer Company uses white oak very largely, with some red oak. About 35% of this material comes from the south and about 65% from Indiana.

Showers Brothers Company, Bloomington, cut only those woods that are native to the southern part of the state. They include in their work the different varieties of oak, poplar, beech, maple, sycamore, elm, ash, and hard gum with occasional logs of walnut and cherry. The last two are taken from southern Indiana. A direct quotation from the letter of their secretary is extremely suggestive. "There is yet quite a quantity of timber in this section of Indiana. It is, however, becoming very much scattered. The visible supply of veneering timber in Indiana is rapidly diminishing. In my opinion *within four or five years it will be necessary for the larger mills to draw from out of the state a large part of their logs.* The quality of southern Indiana logs, principally the oak varieties, is the best in the country for veneering purposes. The texture of the grain and of the figure being far superior for cabinet purposes to the southern varieties. We use in our veneering mill alone about 35,000 feet log measure of timber per week. It is my opinion that further development of the veneering industry will do more to save the diminishing supply of timber in this state than any other one thing, as in working timber into veneer an enormous saving in waste is effected."

The Diamond Veneer Company uses only quartered oak in its operations, buying flitches from the saw mills and not buying logs. The company estimates that about 90% of its stock comes from Indiana mills, but has no knowledge as to the sources of supply of the mills.

The Putnam Oak Veneer Company uses practically any of the native woods of Indiana. The woods principally used are white, burr, and red oak, ash, hickory, bass wood, soft elm, poplar, walnut, black gum and beech. "Probably 20% of the wood, such as gum, cottonwood, poplar, red and white oak, comes from our native forests, the balance comes from the

south, where the timber is better as to size and cheaper as to price than our own timber. In my judgment we do not furnish over 40% of the lumber consumed in the state, the balance comes from the south. As is a well known fact, Indiana oak is the finest grade of oak that was ever grown in this continent. It is beyond the power of any living man to produce the wonderful forests of oak, poplar, ash, and walnut that once covered this state of ours. We gather our supply from all over the state. Fifteen to twenty-five years ago we were able to buy bunches of oak timber in from 75,000 to 100,000 feet lots, but now we pick up a tree here and there where possible. The condition has been reached that the state is swept practically clean of all its native oak."

Mr. Howard I. Young, Secretary of the National Veneer Association, estimates that there is in the neighborhood of ninety million feet of oak veneer manufactured in Indiana annually. This output is classified broadly into two parts, quartered oak veneer amounting to about sixty-eight million feet, and rotary cut oak veneer, amounting to twenty-two million feet. While much of the oak material is secured from Indiana, Ohio, and Illinois, a very material quantity of oak logs are shipped from the southern states to fill the demand for this class of material.

These extracts indicate that for many years selective cutting has been practised and in fact has been increasing as the years have passed. Timber area after timber area has been swept clean of its black walnut, its yellow poplar, its white oak, its cherry, and other trees of high grade and large size. As a result the forests that are left are composed of less desirable forms, and it is these less desirable forms that are furnishing the forest of the future in so far as any such future is to be hoped for. It is very evident from this statement of facts that if the high reputation of Indiana timbers is to be maintained and that if Indiana continues to be able to provide material for its own wood manufacturing industries, some close attention is demanded along the lines of the regeneration of existing wood tracts with desirable species. This may mean planting in certain open places, but even in spite of the considerable expense involved in such a process, the results reached would far exceed [illegible] in value the cost incurred. While the experimental period at the State Forest Reserve has as yet been too brief to furnish data for authoritative conclusions, the indications all point to the fact that high grade [illegible] trees such as yellow poplar, black walnut, and ash will grow as rapidly as [illegible] the catalpa and black locust.

Not only are the indications that they will grow as rapidly, but also that they will maintain themselves in a healthy state, in good form and be relatively free from insect attack and fungus disease. While it is true that the oaks which are at present in very high demand will not make such rapid growth, it has been found that they will make a sure and healthy growth and that in all probability a natural regeneration of the existing wood tracts with our native oaks and other high grade timbers would be easily within the range of possibility, were it not for over-pasturage, damage by fire and destructive lumbering.

All of this means that in the use of the wood lot or small timber tract the owner should have constantly in mind *its perpetuation in unimpaired value.* No tree should be cut unless there is evidence that its place will be quickly taken by another equally desirable form and this evidence is always at hand in the presence of an abundant young growth. If such a young growth is not present, cutting cannot be done without diminishing the value of the stand. In every case the owner should regard a stand of timber as an investment from which he should derive a constant revenue, while at the same time the investment remains unimpaired. The scarcity of high grade timber, the eagerness with which it is sought and the relatively high stumpage values all combine to tempt the owner to such an impairment of his investment. but a yielding to the temptation is an indication of poor business judgment.

It may be necessary in many instances to reinforce the relatively slow process of natural seed regeneration. This may be done cheaply and efficiently in many ways, which are self-suggestive, yet which will bear restatement. The weeds and brush may be cut away from the immediate neighborhood of the "mother seed tree" in order that the seeds may come in closer contact with the ground when they fall, thus greatly increasing their chances of successful germination. If the soil is hard and compact it may be broken with a hoe or plow so as to furnish a more satisfactory seed bed. In some cases where the litter of leaves is quite deep it may be advisable to rake it off in order to expose the mineral soil and even in extreme instances to burn it off, although burning over a tract to reinforce natural seed regeneration is an extremely doubtful process in unskilled hands. The methods suggested do not cover wide areas and are the ordinary methods used in the management of other crops. Whatever form they may take the result sought is the same, an increase in the number of seeds germinating by improving the character of the seed bed.

It is very obvious from this résumé of conditions that unless the owners of existing wood lots attack the problem in an intelligent way the time is not far removed when practically all of the material used in our wood manufacturing plants will have to be shipped in from other states.

The conclusion to be drawn from the statements in the above paragraphs are all but obvious. Practically all of our forests are in private hands and it is very evident that the timber problem in Indiana is to be solved by private forestry. The obstacles to private forestry are summarized by Treadwell Cleveland, Jr.,[3] as fire risk, ill-devised taxation and cheap stumpage. The first two of these he suggests are "artificial obstacles" which may be removed by suitable state legislation. Concerning the third, Mr. Cleveland says: "Cheap stumpage is the chief material obstacle to the wide extension of private forestry. Forestry involves an investment in growing timber. If the investment is to show a satisfactory profit, the product must not sell too cheap. As long as the product sells cheap, expenditures will not be made to produce it, and the lumberman will continue to be the nomad and the speculator which past conditions have inevitably made him. In order to hold out inducements to private enterprise, forestry must offer a reasonable margin of profit above the cost of growing the timber.

"This obstacle to forestry is being steadily removed by the depletion of the virgin forests and the consequent rise in stumpage prices. Already the scarcity of supplies has resulted in a number of cases in the holding of tracts for more than a single crop."

It is evident that if the timber supply of the state be maintained there must be cooperation between the state and private owners. Just what form state laws for the encouragement of forestry should take is not perfectly clear. It is evident, however, that legislation should develop out of state conditions and until the resources of cooperation have been exhausted, definite legislation should not be enacted. An examination of State laws encouraging forestry shows that they may be grouped under two general heads. First, those which seek to stimulate tree planting by bounties or tax exemptions; second, those establishing Forest Commissions and, in late years, State Foresters charged with duties suggested by the conditions in the state creating these offices. The laws under the first group have been, almost without exception, ineffective and in very many

[3] Status of Forestry in the United States. Forest Service Circular 167, pp. 23-24.

cases have been repealed and in a considerable number of other cases declared unconstitutional. Such laws "have had some slight educational value, but they have led neither to the planting nor to the preservation of forests."[4]

Laws falling under the second group, on the contrary, seem to have greatly advanced the cause of forestry. This has been done mainly by gathering information, cooperating with private land owners and giving advice concerning the care of private holdings and tree plantings. In many states, state forests have been established and these have in every instance proved of high value. To quote directly from Mr. Cleveland.[5] "These State forests represent a line of state action which has been pre-eminently successful. New York leads the list in State forest area (1,611,817 acres), followed by Pennsylvania (863,000), and Wisconsin (253,573 acres.) The smaller attempts of Minnesota, Michigan, Connecticut, Massachusetts, New Jersey, Indiana, etc., are all important. The State forests speak for themselves. First, they furnish object lessons of great value; second, they form the nucleus of what some day must be the principal center of state forest work. It is a fundamentally sound policy for the State to own land, especially land which does not offer the conditions necessary for prosperous settlement."

Under existing conditions in our own state, the most important and immediate duty is an extension of knowledge concerning the significance of existing timbered areas in their relation to the future of the forests and of the wood working industries; of their value as investments; of methods of management and utilization which will secure the maximum revenue without deterioration of the stand; of the importance of reinforcing natural seed regeneration and of a more general practice of wisely considered afforestation methods. The most casual inspection of the present timbered areas would prove sufficient to convince the most skeptical of the importance of intelligent and persistent effort along the lines indicated. If, in addition, we consider the large area of land at present utterly unproductive, areas which are increasing in extent each year, some wisely planned and judiciously applied remedial measures seem absolutely imperative. The Academy of Science could do much as a body and through the efforts of its members to aid in this work. The problem is sufficiently acute to

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[4] and [5] Status of Forestry in the United States. Forest Service Circular 167, September, 1909, p. 21.

indicate that the time for destructive criticisms of present attempts for its solution has passed, and that the time has arrived for cooperation in this work. If this cannot be given, the criticism should at least be constructive. In eight years of service on the State Board of Forestry, it has been my privilege to hear many sharp criticisms of its personnel and its work, but in all that time there has come neither to the board nor to any individual member of it a single suggestion as to how either might be improved.

It may be assumed without argument that a complete invoice of the present stand, as to amount, composition and distribution is absolutely necessary in order to secure results which are even approximately satisfactory. As a matter of fact, it has been demonstrated that with the present sources of information and with the present limitations as to the functions of the State Board of Forestry the collection of such data is absolutely impossible. Yet, it is evident that such a census of our forests and such knowledge of their composition and distribution are conditions precedent to any successful work looking to the maintenance of our timber supply. It is at this point that the state should cooperate with the National Forest Service. In many states, such a forest census has been or is being taken, the Forest Service detailing experts for the work and the state paying the expenses of the survey. Such cooperation gives the most complete, the most accurate and the most easily comparable results in the shortest time and at the least expense. If such cooperative work is impossible, then the Board of Forestry should as rapidly as its means will permit, collect and organize information covering these points. The slightest consideration of the future of the forests and of the wood-working industries of the state will show that the results of such a census would prove of the highest importance, not only in determining the policy of the state but in emphasizing the significance and value of existing timbered areas.

There is need also of much more exact and indeed of much additional knowledge in relation to the selection of species for planting in the different soil, drainage and exposure conditions of the state. There is need also of equally exact knowledge concerning the silvical qualities of these species, the most economical methods of propagation, their spacing in plantings, their cultivation and care and above all their rate of growth under variant conditions. The securing of such data is a matter of years of continuous experimentation and this work the state is properly under-

taking on the State Reserve. There is necessity, however, that the fact should be kept in mind that results sufficiently definite to prove of general application can only be secured as the results of large series of experiments continued through many years. In order, however, that such work may reach its highest value there should be close cooperation with individual land owners throughout the state. Cooperative experimental plats should be found in every part of the state. The seedlings should be furnished from the state reservation and should be planted and cultivated under regulations prescribed by the State Board of Forestry. Regular reports should be made by the owners to the Board and regular inspections of such plantings should be made by its Secretary. The conclusions resulting from observations covering a wide range of conditions and involving varying degrees of care and attention would evidently be of much greater value than those possible under present methods.

There is cause for congratulation in the fact that the state realizing the gravity of the problem confronting it is taking steps to avert the disaster which our rapidly waning timber supply seems to indicate. Caution in such matters is of course wise, but it should not be forgotten that as a rule a Fabian policy is ineffective in acute cases. There is every reason for confidence, however, in believing that no backward steps will be taken and that as the years pass the development of a wise forest management on the part of individual land owners, will under the guidance of the state be far more rapid than in the past. There is reason for hope also in the general observance of Arbor Day for it gives assurance that the next generation will have a fuller knowledge and a truer appreciation of the value of our forests than their parents ever possessed.

Summarizing; the present forestry conditions in Indiana being as stated, three great lines of work suggest themselves as immediately necessary if the timber supply of the state is maintained:

1. An educational propaganda emphasizing the importance of correct forest methods, the value and potentiality of existing wood lots, and of the importance of reclaiming waste lands by tree planting.

2. A census of the present timber stand, its composition and its distribution.

3. Cooperative experimental work on the part of the state and individual land owners, for the determination of suitable species for afforestation, their silvical qualities and their rate of growth.

Quite apart from any sentiment, no more acute problem nor one which directly affects more business and individual interests confronts the state. Others may be of greater magnitude, but certainly no other one touches so intimately such wide and varied interests.

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# PROCEEDINGS

OF THE

# Indiana Academy of Science

TWENTY-FIFTH ANNIVERSARY

1909